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**General Technical
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North American Workshop on Monitoring for Ecological Assessment of Terrestrial and Aquatic Ecosystems

Taller Norteamericano Sobre Monitoreo para la Evaluación Ecológica de Ecosistemas Terrestres y Acuáticos

Mexico City
September 18 - 22, 1995

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ABSTRACT

This publication contains the paper presentations of the North American Workshop on Monitoring for Ecological Assessment of Terrestrial and Aquatic Ecosystems held in Mexico City on September 18-22, 1995. The general objective of this Workshop was to exchange information on ecological monitoring approaches and technologies that are both useful and cost-effective for assessing ecosystem condition and health. In addition, the Workshop was also designed to stimulate cooperation and collaboration among North American scientists through future information exchange, networking, reciprocal training, and development of cooperative projects on monitoring for ecological assessment of forests, rangelands, agroecosystems, estuaries and coastal waters, wetlands, and surface waters. Specific Workshop objectives included: presentation and discussion of scientifically defensible ways to monitor and assess the status of, and changes and trends in, ecosystem condition, with a focus on the following issues: survey design, indicator evaluation, data interpretation strategies, and information management and quality assurance; discussion of frameworks associated with ecological monitoring and assessment; and encouraging further scientific cooperation and information transfer in the field of monitoring for ecological assessment of North America. A Workshop synthesis and recommendations for future cooperation and collaboration on this matter are also included in these proceedings.

WORKSHOP SPONSORS

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Editor's Note: In order to deliver symposium proceedings to users as quickly as possible, many manuscripts did not receive conventional editorial processing. Views expressed in each paper are those of the author and not necessarily those of the sponsoring organizations or the USDA Forest Service. Trade names are used for the information and convenience of the reader and do not imply endorsement or preferential treatment by the sponsoring organizations or the USDA Forest Service.

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General Technical Report RM-GTR-284

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Mexico City
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Editor:

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Fort Collins, CO

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Preface

Society and governments are increasingly challenged by the global realities of ecological and economic interdependence. Issues that synthesize the complexity of these realities center around the well-being of people and the healthy condition of ecological systems. Harmonizing the relationships between these two components of the sustainability equation constitutes the most critical challenge society and governments face today and into the twenty-first century. In this equation, the integration of human and ecological systems becomes a necessary condition to confront and mitigate the deleterious effects of "global change". That is, the full range of transformations and interactions concerning the global environment, natural and human-induced, which may alter the capacity of Earth to sustain life (i.e., alterations in climate, land management and productivity, oceans or water resources, atmospheric chemistry, and ecological systems). Understanding and managing these drivers of change has become a common global mission and the most important task for achieving the sustainability of ecosystems and ensuring the well-being of people and society.

Efforts to better understand and manage the drivers of change are also challenged by the socioeconomic and political complexities that are shaping the twenty-first century. Natural and human-induced drivers of change are hierarchically interrelated, and research and mitigation actions to confront them should go beyond geopolitical boundaries. Consequently, cooperation and collaboration among nations becomes a prerequisite for achieving successful and meaningful results. However, international cooperative actions need to be adapted and become more responsive to a number of emerging global conditions and trends. That is, the emergence of regional free-trade economies, the proliferation and diversification of legally and nonlegally binding international agreements, the shrinking of national bureaucracies and budgets, the return of power to local governments, and the privatization of national lands and the public sector. International cooperation approaches that fail to take into account these emerging contexts cannot be successful in confronting the challenges of entering into the twenty-first century.

In North America, as a regional system shared by several nations, understanding the vulnerability of ecological systems to the different drivers of change is fundamental to ensuring their sustained productivity and societal value. As in other regional systems, the availability and health of natural resources and ecological systems are indisputably the foundation for economic and human development. Both components are inseparable dimensions of the sustainability equation. Sustaining these systems, and particularly managing and mitigating change in ecological systems that have already been damaged, are critical challenges that this regional system faces. For North American countries, a coordinated set of actions to confront these challenges is particularly important given their geographic adjacency, and ecological, economic, and cultural linkages and interdependencies. From this perspective, the economic and environmental performance of these countries becomes an essential condition for achieving and securing healthy ecological and economic conditions throughout the regional system. Consequently, the sustainable development of this regional system can only be secured through truly effective actions of international cooperation and collaboration.

To address the above concerns, a number of government and non-government institutions from North America held a workshop on monitoring for ecological assessment of terrestrial and aquatic systems in Mexico City on September 18-22, 1995. Participants from these countries benefited greatly from the exchange information and technologies that took place during this event. The Workshop also created important conditions for furthering future cooperation and collaboration among North American countries on monitoring for ecological assessment of forests, rangelands, agroecosystems, estuaries and coastal waters, wetlands, and surface waters. These proceedings, therefore, constitute a tangible product of work in partnership. Working in partnership across countries and institutions made possible the successful completion of this North American Workshop. On behalf of the sponsoring institutions, I want to thank the many individuals who contributed to the success of this important event.

Dr. Denver P. Burns
Director, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service

Foreword

This publication constitutes an important tangible output from a unique North American workshop held in September, 1995 in Mexico City. The workshop on "monitoring for the ecological assessment of terrestrial and aquatic ecosystems" brought together ecologists and other experts from Mexico, Canada and the United States to consider the challenges and opportunities involved in the ecological monitoring and assessment of terrestrial and aquatic ecosystems it was understood that air, aerial pathways and the atmospheric deposition of pollutants are directly linked to the status of, and trends in terrestrial and aquatic ecosystems. The papers included in these proceedings are representative of the many diverse topics and issues that were addressed at the gathering.

There was a general recognition that Mexico, the United States and Canada had much to gain by working together in furthering the many facets of ecological monitoring and assessment. One of the key outputs from the meetings was a recommendation to develop a tri-national "Framework for Action" that, amongst other functions, would foster and encourage tri-national cooperation and collaboration in this important field. The United States, Canada and Mexico have been involved in reviews of their monitoring programs and there may well be a "window of opportunity" to design the next generation of monitoring programs so that the information generated is more compatible and more applicable to large-scale regional issues of concern to the three countries.

The human species is now placing unprecedented demands on the assimilative and productive capacities of terrestrial and aquatic ecosystems at all scales up to and including the planetary scale. By design or by necessity these human demands will eventually have to come into a more realistic balance with the inherent carrying capacities of the planet. Ecological monitoring and assessment is not an esoteric academic exercise. Rather it is a science-based approach to gathering and interpreting information on the status and trends in ecosystem condition with the express purpose of detecting and understanding important changes - especially those changes that are being induced by human activity. It reflects a systems or ecosystems approach that both depends upon and complements ecological research and modeling. The improved understanding that results provides an opportunity for more informed and more responsible decision-making at every scale.

The Framework Convention on Atmospheric Change and the Convention on Biological Diversity are illustrative of global instruments that have been strongly influenced by science-based ecological monitoring and assessment. Multilateral agreements such as the North American Agreement on Environmental Cooperation as well as many national, state and provincial policies, legislation and programs are similarly linked to, and dependent on, the availability of science-based information on the conditions of, and trends in, the state of target ecosystems.

The Commission for Environmental Cooperation is pleased to have been one of several co-sponsors of this workshop on monitoring for the assessment of terrestrial and aquatic ecosystems. It is the Commission's hope that the workshop and these proceedings will help to encourage greater cooperation between North American experts and officials so as to enhance the generation, quality, compatibility and use of environmental information in addressing current and emerging environmental challenges.

Dr. Andrew L. Hamilton
Head, Science Division
Commission for Environmental Cooperation

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The U.S. Environmental Monitoring and Assessment Program: The Next Phase

Sidney Draggan, Ph.D.[1]

INTRODUCTION

One of the first things I want to convey to this trinational group is that the task set out for us is to provide data and information that our public health and environmental policymakers and our environmental managers will find to be timely, scientifically-defensible and credible. They urgently need this data and information in making decisions and undertaking activities and projects related to maintaining the health of our citizens and the quality of our national environments. Also, I need to remind you that the formal title of this symposium is the "North American Workshop on Environmental Monitoring for the Assessment of Aquatic and Terrestrial Ecosystems"—it was adopted after much deliberation. Please do not return to your home institutions and describe this gathering to your colleagues and students as a workshop that focused solely on monitoring and observation—our purpose here is to focus on monitoring as well as the human health risk and ecological risk assessment processes that provide solid guidance and feedback to our policymakers, environmental managers and the public.

I have said often that the Environmental Monitoring and Assessment Program (EMAP), a program intended and designed to advance the synthesis of knowledge on ecological condition to promote and strengthen the evaluations of and judgments on that condition has been destined to be viewed in a fragmentary manner due to its name. If the program could have been named the Environmental Monitoring *for* Assessment Program, its unique focus and intent, from the outset, would be clearer to the wide variety of stakeholders that it serves. I hope that we are in agreement here that the assessment process deserves, at least, the same level of attention as that necessarily given to the monitoring component. Also, it cannot be forgotten that monitoring, and assessment, activities require fundamental research to enhance their accuracy continually.

The organization of this Workshop began with requests from several Mexican governmental and academic institutions to EMAP for support through direct collaboration and transfer of EMAP philosophy, methodology and technology. The Workshop gives substance to the traditional outreach responsibility of all modes of research and knowledge generation. It is an ideal way for colleagues to learn jointly about the histories, goals, and outputs of similar endeavors in a relatively efficient manner. Your presence here this week offers strong testament to our intent to learn better way of protecting and managing our unique, and our common, ecological resources.

THE U.S. ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM (EMAP)

The Environmental Monitoring and Assessment Program was designed to conduct research and demonstration activities that can heighten our abilities to gauge and assess the status of, and changes and trends in, U.S. ecological systems. Its research was and is needed, as yet, to implement appraisals that address and resolve such concerns as:

- the effectiveness of national environmental decisions (that is, policies and legislation [and their results—regulations and environmental and public health management activities and projects]). It has been recognized that for the U.S., billions of dollars have been spent to reduce environmental stressors and risks, but that it is virtually impossible to discern—with

[1] *Special Assistant for Science, Office of the Administrator, U.S. Envimmental Protection Agency, Washington, DC.*

any certainty—if adopted policies and legislation, and regulations and management efforts, now in operation have resulted in actual, measurable improvements in the condition of ecological resources or environment-related public health.

- the establishment of national priorities for the use of limited resources, in order to direct human health and environmental quality efforts at those environmental attributes at greatest risk. It is clear that national costs—worldwide— for the protection of environmental quality and subsequently human health have increased steadily since the late 1960s.
- the simultaneous anticipation and disclosure of emerging environmental problems. There is growing understanding that environmental harms can be anticipated reliably (Science Advisory Board 1995). Such programs as the EMAP are instrumental in the generation of the elemental data and information needed to carry out futures studies.

EMAP: NEW DIRECTIONS

During the late 1980s, following recommendations of the ecological sciences research community and the Agency's Science Advisory Board (SAB), the EMAP was initiated by the U.S. Environmental Protection Agency (EPA) with increasing participation by other U.S. Federal and State agencies. At that time, its long-term mission was, and remains, to conduct necessary research on how to reliably and credibly:

- define the status of, and trends and changes in, the condition of the Nation's ecological resources;
- determine the extent of the Nation's ecological resources;
- identify possible causes of the current and changing condition and extent of these resources; and
- report regularly on the findings.

Since its inception, EMAP activity has received extensive review by independent researchers and professional organizations, and by the SAB and the National Research Council. These reviews, while supportive of the intent, design and research products of the EMAP over its first five years have, provided valuable recommendations for strengthening the focus, scope and direction, and the scientific defensibility and credibility, of the Program. Currently, the EMAP is being restructured for its second phase of operation. Several significant changes accompany that restructuring.

EMAP PHASE II

The second phase of EMAP activity, while retaining the overarching mission and long-term goals of its predecessor, has placed the improvement of the quality and defensibility of its science at the head of its tasks. Recognizing that reliable information is generated on the status of, and trends and changes in, the condition of ecological resources only through better understanding of the reference (or baseline) state of ecosystem components and processes (that is, ecosystem structure and functioning) the Program is being restructured to focus now on:

- development of a coordinated network of intensive, biome-based monitoring sites representative of the Nation's ecological resources. This activity will capitalize on, and provide value-added support to, such existing research sites as those supported by the National Science Foundation (Long-Term Ecological Research and Land Margin Ecosystem Research network of sites), the Department of Energy (National Environmental Research Park sites), the U.S. Geological Survey (National Water Quality Assessment Program), the Forest Service (Forest Health Monitoring Program), and the multiagency Clean Air Status and Trends monitoring network. EPA's EMAP, with its experience in partnering with other agencies would provide leadership in enhancing cooperation among such sites, augment areas of investigation for generation of more comprehensive ecosystem knowledge, and foster the use of consistent monitoring, and assessment, approaches and tools to assure a higher level of consistency in Federal and State environmental monitoring for assessment efforts, overall;
- establishment of regionally-based assessments of the condition of specific geographic areas of the Nation that have been targeted for enhanced ecosystem protection and management. These Geographic Initiatives (of 2- to 3-year lifetimes) are expected to commence with three efforts: the Mid-Atlantic Integrated

Assessment, Pacific Northwest Forests and South Florida. A component of the monitoring done within these Initiatives will be linked with the monitoring conducted at the intensive sites noted above. Also, these activities will capitalize on the existing and continuing partnerships that the EMAP has developed with such agencies as the National Biological Survey, the Bureau of Land Management, and the Department of Agriculture; and

an expanded reliance on investigator-initiated research that focuses primarily on the identification, refinement and verification of indicators (and indices) of ecosystem condition. Such evidentiary biological and ecological metrics are required for us to discern and understand the changes and trends that can serve as the pulse indicative of the condition and integrity of ecological systems. Particular attention will be paid to disclosing the: 1) roles of spatial and temporal scale to integrated, cross-ecosystem assessment; 2) appropriate chemical stress indicators; and importantly, new and reliable indicators for such "non-traditional" environmental stresses as land use and land cover change, and habitat loss.

NEW INTERAGENCY INITIATIVE

In the Summer of 1995, following recommendations of the National Science and Technology Council's Committee on Environment and Natural Resources, the Office of Science and Technology Policy established a Task Force to develop a strategy and recommendations for the design and ultimate implementation of an integrated, interagency ecological research and ecological resource (that is, ecological system[1]) condition monitoring network[2]. This effort is undertaken with the understanding that there exists within the U.S. a plethora of ecological research and monitoring activities designed to fulfill the individual needs of Federal agencies or the specific requirements of legislation these agencies must implement. Only some of these activities have been combined successfully—for example, within such efforts as the EMAP. Each of the programs now operating exhibits its own strengths and weaknesses as well as areas of overlap with other efforts and uniqueness; nonetheless, greater value can result from further coordination of these wide ranging activities. A final report from the Task Force is expected by December 1995—to be followed by a synthesis workshop. There is little question that EMAP in its second phase of activity will play a substantial guidance role in the development of this interagency initiative. Information generated under EMAP's unique probability-based sampling design and index period sampling approach will be melded with data collected at fixed index sites following more traditional time-series based investigations. Of particular importance will be the contribution made by EMAP's pioneering systems for data and information management and quality assurance. The information system is now available for use by EMAP's participants, the scientific community and the public—all of whom can access[3] the verified and validated data and information generated by the Program along with the metadata defining the contexts of sampling and assessment activity. The results of this interagency initiative when implemented fully are expected to answer in a more appropriate manner questions about the condition of our ecological resources for a wider range of spatial scales and decisionmaking needs.

NECESSARY LINKAGES

Integrated ecological risk assessments, those capable of combining data and information collected within differing ecological resources and at differing spatial and temporal scales require powerful synthesis principles and mechanisms. To date, such synthesis principles and mechanisms have been unavailable (AERC 1989, ESA 1993 a,b); but, new initiatives have begun. These efforts are new centers funded by the National Science Foundation and are now adding substance (in terms of defensible, multidisciplinary, science-based activity) to necessary environmental risk assessments, overall. The Center for Ecosystem Analysis and Synthesis[4], headquartered at the University of California in Santa Barbara and the Center for Environmental Decisionmaking (a joint efforts of Oak Ridge National Laboratory and the University of Tennessee)

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[1] *This term refers to such resource systems as forests, surface waters, estuarine and coastal areas, agricultural ecosystem and rangelands.*

[2] *nteragency Ecological Research and Monitoring Sites Network.*

[3] *Via the World Wide Web at <<http://epawww.epa.gov/emaphome>>; <<http://www.epa.gov/docs/emap/>>; and, <<http://dolphin.gbr.epa.gov>>.*

[4] *Via the World Wide Web at <<http://www.ceas.ucsb.edu/>>.*

are appropriate points of linkage for any environmental monitoring for assessments now being planned or operating.

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Ecological Monitoring of Ecosystems in Mexico: A Message from the Secretariat of Environment, Natural Resources and Fisheries

Dr. Oscar Gonzalez Rodriguez[1]

1. SALUTACION

Señoras y Señores

A nombre del gobierno de mi pais y de la M.C. Julia Carabias Lillo, secretaria de medio ambiente, recursos naturales y pesca, me es grato dar a ustedes la mas cordial bienvenida a este evento, organizado conjuntamente por las dependencias aqui representadas de los tres paises: Canada, E.U.A. y México.

2. AGRADECIMIENTOS

Agradezco el esfuerzo realizado por todos ustedes en realizar este "Taller de Monitoreo para la Evaluación Ecológica de Ecosistemas Terrestres y Acuáticos" que hoy se inicia.

En particular mi reconocimiento a las dependencias que directamente participaron en la organización, como son:

Canada

Environment Canada

Natural Resources and Forestry Canada

Agriculture Canada

Commission for Environmental Cooperation

E.U.A.

Department of Agriculture, Forest Service

Environmental Protection Agency

Department of the Interior, National Biological Service

United States Department of Commerce, National Oceanic and Atmospheric Administration

México

Universidad Aútonoma Chapingo

Colegio de Postgraduados

Universidad Nacional Aútonoma de México

Universidad de Sonora

Centro de Investigaciones Biológicas

Universidad Aútonoma de Chihuahua

Universidad Aútonoma de Nuevo Leon

Universidad "Antonio Narro"

SAGAR-INIFAP

SEMARNAP

3. IMPORTANCIA DEL TALLER

El tema sobre monitoreo ambiental de ecosistemas, toma especial relevancia en nuestro tiempo, debido a la urgencia de transitar al uso sustentable de los recursos naturales, que en principio implica frenar los procesos degradantes a que han estado sujetos.

"La estrategia nacional de desarrollo, busca un equilibrio global y regional entre los objetivos económicos, sociales y ambientales, de forma tal que se logre contener los procesos de deterioro ambiental e inducir el ordenamiento ecológico del territorio"

Con base en este postulado del plan nacional de desarrollo, se reconoce que el aprovechamiento racional de nuestros recursos naturales, en armonia

[1] *Undersecretary of Natural Resources, SEMARNAP, Mexico.*

con su protección y cuidado, solo puede lograrse disponiendo de información veraz actualizada de las caracteristicas cualitativas y cuantitativas de los propios recursos y ecosistemas, asi como del grado y dinamicá de deterioro que presentan.

Para ello es indispensable realizar acciones institucionales concertadas sobre evaluación y monitoreo de ecosistemas tanto acuáticos como terrestres.

En México se cuenta con importantes experiencias sobre monitoreo de ecosistemas y sus recursos, como el agua, suelos, bosques y selvas; pastizales, agroecosistemas, calidad del aire y otros, sin embargo reconocemos que son esfuerzos aislados y que en la mayoria de los casos falta mucho por ahondar en rubros como la sistematización, actualización tecnológica, normatividad internacional, equipamiento, conectividad, marco legal y otros; que son temas que sin duda seran analizados a fondo en este taller.

Creemos que el evento es una excelente oportunidad para poder intercambiar conocimientos y experiencias que nos permitan desarrollar nuestras capacidades en la materia de manera coordinada y en colaboración con instituciones de Canada y Estados Unidos, asi como de agencias como la EPA (Agencia para la Protección del Ambiente) y la CEC (Comision para la Cooperacion Ambiental), a quienes nos preocupa el manejo adecuado y desarrollo de nuestros recursos, toda vez que compartimos una extension territorial de interes comun, que alberga una gran biodiversidad en variadas formaciones y ecosistemas. Dicha extension representa casi el 16% del total mundial, en 21.3 millones de km2.

4. RECURSOS NATURALES DE MEXICO

Sobre una extension de casi 2 millones de kilometros cuadrados, México constituye un corredor natural entre dos grandes regiones del globo, lo que le ha conferido una gran diversidad de suelos, orografia, climas y especies bióticas. En este pais, concurren la gran mayoria de ecosistemas existentes, por lo que se le ha clasificado por su biodiversidad en el cuarto lugar a nivel mundial.

La variedad ecológica existente incide en una notable riqueza biótica que se manifiesta en un amplio numero de especies y variedades vegetales y animales. Por citar algunos ejemplos, México se destaca por poseer el mayor numero de especies de pinos, encinos y cactaceas.

En lo referente a tipos de clima, contamos con casi todos, excepto los mas frios, pero fuera de ello tenemos calidos, secos, semisecos, semihumedos, templados, semitemplados y esteparios. El caso de nuestros suelos es similar, presentandose una gran variedad de unidades de suelo, cuyo potencial hace permisible la vida silvestre, asentamientos humanos y actividades productivas.

En materia de recursos hidricos, México registra una precipitacion pluvial media al año de 780 mm, lo que equivale a un volumen aproximado de 1.5 billones de metros cubicos anuales; el escurrimiento en los rios se estima en 410 mil millones de metros cubicos, mientras que el almacenamiento en cuerpos naturales como lagos y lagunas se calcula en 14 mil millones de metros cubicos.

Este potencial de recursos constituye un activo fundamental para el desarrollo del pais. Por ello, tenemos que impulsar un proceso de desarrollo que haga posible la utilizacion adecuada de los recursos, que no los agote y que permita generar un conjunto de posibilidades para las comunidades mas rezagadas y para toda la sociedad: que sea nuestra base para mejorar, sin comprometer, ni mucho menos reducir, las expectativas de desarrollo de las futuras generaciones.

La existencia de esta riqueza natural ha sido y es aun abundante, sin embargo, su aprovechamiento ha atendido una gran diversidad de criterios y politicas, que en todo caso aparecen como un proceso con elementos aislados, dispersos y no siempre compatibles, esto es, exentos de una estructura organizada en forma conjunta. Todo esto ha propiciado esquemas de presion y agotamiento subito de los recursos naturales, que se traducen en un grave deterioro ambiental, caracterizado por la deforestacion, la erosion de los suelos y el agotamiento de los mantos acuiferos; como fenomenos que se convierten cada vez mas en obstaculos para el desarrollo económico y social.

A partir de ello y afrontando el reto que implica revertir el deterioro de nuestros recursos naturales, el Congreso de la Union Mexicano aprobó y dió origen a una nueva dependencia del ejecutivo federal que es la SEMARNAP, a fin de contar con una estructura que coordine los esfuerzos de gobierno y sociedad en la consecucion de un desarrollo sustentable a largo plazo.

La semarnap, asi ha integrado areas estratégicas del sector productivo como son la pesca, los bosques, y el agua con la gestion ambiental. Asimismo se trabaja en ofrecer una plataforma de participación social mas amplia para lograr los objetivos de un desarrollo sostenible.

Señoras y señores asistentes, agradecemos la oportunidad de abrevar de sus conocimientos y de intercambiar experiencias con la conviccion de que el proceso de alcanzar la sustentabilidad, requiere de un seguimiento preciso de la accion del hombre y la naturaleza en la evolución o deterioro de nuestros recursos, posibilidad que nos ofrece el monitoreo ecológico y la evaluación permanente de los propios recursos.

No ha sido facil abrir los espacios de la temática ambiental para el pais y ubicarla en su justo papel de promotor del desarrollo sostenible. Nos encontramos entre las presiones cotidianas de quienes ven en lo ambiental el freno al desarrollo y quienes ven en el desarrollo la amenaza de la destrucción de la naturaleza.

Nuestro compromiso, es fortalecer nuestra capacidad de gestion que nos permita soportar politicas ambientales mas agresivas que urgen en nuestro planeta, si es que nuestro objetivo es devolverle a nuestros hijos el patrimonio que nos han prestado.

SUBJECT I: CURRENT PERSPECTIVES ON ECOLOGICAL MONITORING FOR ASSESSMENT OF TERRESTRIAL AND AQUATIC ECOSYSTEMS

In this session, the invited speakers set the stage for addressing the relevancy of ecological monitoring for assessment of ecosystems in North America. Central to their presentation was the description and discussion of why the subjects to be addressed in this Workshop are important for the participating countries.

Current Perspectives on Ecological Monitoring and Assessment

T.G. Brydges[1]

Abstract.—Many of the current environmental issues, such as acid rain, long range transport of toxic materials, stratospheric ozone depletion and climate change, cause environmental effects at the regional and global scales. In order to develop a full understanding of the environmental consequences of these issues, it is necessary to have information from large geographical areas. Consequently, it is important that Canada, the U.S.A. and Mexico have monitoring programs in place to evaluate the comparative effects of these issues and to understand the interaction of these stresses on our environments.

Not only do these environmental stresses affect large areas, the appropriate control programs also require input from many countries. Therefore, it is important that we have ecological monitoring and assessment programs in place that develop the scientific rationale for control programs and that can also evaluate the effectiveness of these multi-lateral control programs. In addition, it is also important that we have monitoring and assessment programs in place that can give us early warning of any new problems so that they can be resolved at the earliest possible time and with adequate scientific support.

INTRODUCTION

Prior to the mid 1960s, most pollution problems in North America were of a local nature, where effluent pipes were discharging to lakes and rivers or smoke stacks discharging to the atmosphere at low levels. The environmental effects were generally quite visible and easy to define and were directly related to the particular effluent source. The solutions could be equally obvious and indeed many of our problems of this nature have been solved by appropriate pollution control measures.

In the mid 1960s, eutrophication became a major concern in the Great Lakes, particularly Lake Erie. This problem introduced new dimensions to pollution problems that complicated the science of defining the problem and the solution, and in developing effective control action. For example, phosphorus in industrial and domestic effluents lead to increased algae growth, which in turn lead to oxygen depletion and other effects that created the overall environmental disruptions associated with eutrophication. The pollutant itself, in this case phosphorus, was not the immediate problem and it did not reach toxic levels or cause any direct damage. It was the <u>indirect effect</u> on algae growth that damaged the ecosystem. Providing an adequate scientific description of the problem and determining that phosphorus control would be an effective solution was the subject of five

[1] *Director of the Ecological Monitoring Coordinating Office, Environment Canada, 867 Lakeshore Road, Burlington, Ontario, Canada, L7R 4A6.*

years of intensive study during the 1960s (International Joint Commission 1969). Once the scientific issues had been resolved, it was then necessary to develop an international agreement between Canada and the U.S.A. to implement control measures which began in the early 1970s. Monitoring and assessment programs are continuing to this day.

In the 1970s and 80s the issues of acid rain, stratospheric ozone deletion and climate change became dominant problems in the environmental field. These problems have introduced further complicating dimensions to defining the environmental problem. In particular, the long range transport of pollutants from emissions to the point where environmental damage occurs. Climate change reaches the ultimate level of long-range transport since greenhouse gases released at any place on the Earth may influence the climate with consequences felt in almost any other area of the globe. It is, therefore, necessary to have global pollution controls that require international agreements, such as the Canada/U.S. Air Quality Accord and the Montreal Protocol on Substances that Deplete the Ozone Layer.

A further complicating factor now is that the environmental effects of these various stresses are linked. For example, increasing nitrogen deposition to nitrogen limited forests may result in increased carbon dioxide uptake from the atmosphere which would be a benefit to controlling greenhouse gases (IPCC 1994). Conversely, it has been hypothesized that increased nitrogen deposition may lead to detrimental effects in forests through a variety of mechanisms (RMCC 1990). The sulphur dioxide emissions to the atmosphere that lead to acid rain damage have been shown to create a global cooling effect, offsetting some of the global warming brought about by greenhouse gases (IPCC 1994).

These factors result in immense difficulties for ecological science to define the changes that are observed in the environment, to determine their exact causes and to define corresponding control measures.

THE ECOLOGICAL MONITORING AND ASSESSMENT NETWORK

The Ecological Monitoring and Assessment Network (EMAN) that we are establishing in Canada has the primary goal of defining what is changing in the environments and why. It is generally not very difficult to measure changes in the environment such as atmospheric composition, forest condition, agricultural productivity and aquatic nutrient concentrations. It can be quite a different matter to define, in scientifically defensible terms, the causes of these observed changes. However, that is the challenge that we set before the scientists working in the EMAN.

The four general objectives for the EMAN may be summarized as follows:

1. <u>To measure and define the effects of the various stresses on the environment and their interactions.</u> As indicated in the Introduction, not only do various pollution sources cause problems by themselves, such as sulphur dioxide emissions leading to acidification of surface waters, but there are interactions among the stresses. For example, monitoring records are already long enough to give some indication of the interactions between climate variability and the response to changes in acid deposition. Keller et. al. 1992, have documented long-term changes in lakes near Sudbury, Ontario, following sulphur dioxide emission reductions from the local smelters. From 1982 to 1987, they observed the expected trends of improving pH and ANC. However, these trends completely reversed in 1988 when both lake pH and acid neutralizing capacity (ANC) were the lowest values on record. The results were explained in terms of drought conditions of 1987 that resulted in re-oxidation of sulphate stored in the watershed. Subsequent rains caused a pulse of acid that reacidified Swan Lake for the entire year of 1988 with residual effects extending into 1989.

The result of these complicating factors is that we are frequently dealing with incomplete science. Since the effects of many of these pollution stresses are exerted over long periods time, ie. decades, and through complex ecosystem mechanisms, even with the best of environmental information, it is often necessary to proceed with pollution control measures on the basis of the best scientific judgement or scientific consensus. Ecologists are making great efforts to bridge the gap between laboratory experimental studies and full-scale pollution control mea-

sures by conducting whole lake and small ecosystem experiments. A recent review in Science, (Carpenter et. al. 1995) describes the results of a number of large-scale examples that have had direct influence on eutrophication and acidification problems and experiments are now addressing the climate change issue. These large-scale environmental experiments provide substantial amounts of information, in that they can come close to simulating the final environmental response to the either additions of pollutants, as in case of phosphorus additions at the Experimental Lakes Area in Canada, or removal of pollutants, as in the reversing acidification in Norway experiment in Norway. However, even these experiments still have some limitations in the length of time that they can be conducted and their ability to incorporate all features of the ecosystem. However, such experiments have been very effective in the past in developing support for pollution control measures and they will certainly play an increasing role in the future as we deal with more and more complex issues.

2. To develop scientific rationales for pollution control measures. The scientific rationale for reducing phosphorus in effluents to the Great Lakes was the subject of many years of scientific work and was still somewhat controversial even at the time that the reductions were implemented. Long-term monitoring has shown that phosphorus control was the correct control action to take, but there are still aspects of the lake response under study (Charlton et. al. 1993, Dobson 1994).

With regard to acid rain, Canada developed a sulphate deposition target which was used to design the sulphur dioxide emission control program. The scientific discussions leading to the development of the objective took place over several years and the corresponding SO_2 emissions control program in Canada has been implemented over the years since 1985 (Canada/U.S. Progress Report 1994). The ongoing environmental monitoring and assessment programs have shown that lower deposition values would be needed to be fully protective of all aquatic systems (RMCC, Aquatic Effects 1990) and this information is now the subject of an assessment of the situation in eastern Canada to be presented to Ministers for decisions in 1997.

An important feature of the large scale global issues that we are dealing with, such as acid rain and climate change, is that the costs of emission controls can be very high but can also be greatly affected by the timing of the implementation. The costs of control might be quite different if industry is given more time to introduce new technologies and phase out old plants vs. retrofitting existing facilities in a short period of time. The corresponding scientific challenge is to define whether we can wait to allow industry time or whether there is sufficient justification for proceeding with emission control action regardless of the costs. Industries and society quite rightly expect answers to these types of questions and this, in turn, places further challenges before the scientific community.

3. To evaluate the effectiveness of existing control programs. Once control programs are in place, society and the industries affected need to know if the programs are providing the environmental protection that they were designed for. This issue is not as simple as one might expect. The examples of the interaction of pollution stresses, described under item 1, clearly demonstrate that we need very comprehensive datasets in order to be able to define the environmental response to emission controls. A simple monitoring program that would just measure sulphate in lakes would be completely inadequate to evaluate the ecological response to the sulphur dioxide control program.
4. To alert society to new problems as they occur. A number of the EMAN facilities were established in the 1960s and early 1970s to study eutrophication of lakes. At that time, when these eutrophication studies were established in the mid 1960s, environmental damage from long range transport deposition of acidic materials was unheard of, stratospheric ozone depletion was no where on the "environmental horizon" and confirmation of a global warming trend was still nearly 20 years away. Yet in eastern Canada, when the environmental effects of the long range transport and deposition of acid rain became an issue, much of the information

about the problem was derived from the studies that had been implemented to study eutrophication. In other words, the good quality comprehensive ecological datasets, although designed for one purpose, were able to provide the initial information needed for a second problem which emerged during the studies. The same data are now being analyzed in terms of climatic variability.

While many details of the monitoring programs are changed and modified as new issues come along, this cannot take away from the fact that the well planned studies were able to provide information on new issues and we have every reason to believe that this situation would continue in the event that new problems emerge.

In summary, we are facing complex environmental problems at the global scale which require global control initiatives and thus, must be supported by global scientific activities.

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Integrated International Monitoring: Strategic Design

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Abstract.—A strong need has been identified to monitor the ecosystem health and imposed stresses over broad areas of the earth. A number of considerations are proposed for developing a strategic design for such programs, including recommendations that these programs should: (1) Clearly establish their purpose or purposes; (2) Test, at known levels of confidence, unambiguously stated hypotheses; (3) Build on coordinating and expanding existing environmental monitoring activities to form integrated broad-scale monitoring networks; (4) Function at several spatial scales with more intensive monitoring efforts encompassed within sparser, broad-scale networks of sites; (5) Be based on integrated sampling site frameworks using both fixed position and probability-based site selection; (6) Use stratified sampling within ecologically relevant environmental components; (7) Monitor indicators of both ecological conditions and of the stresses being applied to the environment; (8) Develop consistent, program-wide procedures for data management and graphic display; and (9) Include a rigorous quality control and quality assurance system based on the use of performance-based evaluations of monitoring methods and data.

INTRODUCTION

Global increases in human populations and accompanying industrial and agricultural development are having a profound effect on the earth's biosphere. Ecosystem degradation is becoming more and more widespread, and the capacity for the environment to support sustainable development of our societies is being threaten. To evaluate the magnitude and severity of environmental degradation and to identify developing problems, we must monitor the status and trends of indicators of ecosystem health and imposed stresses over broad areas. Although many environmental monitoring programs are already in place on local and regional scales, there are far fewer monitoring efforts providing consistent data and information on ecological health over broad areas of the earth. There is a strong need for developing such international monitoring programs to assess continental and global scale ecological health by coordinating efforts across regional and national boundaries.

To develop such programs, calls for linking measurements and observations gathered by various agencies in different countries into monitoring networks that provide sets of indicator measurement data that provide a solid basis for developing interna-

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tionally consistent broad-scale environmental assessments. Many programmatic design issues must be considered and agreed upon to develop such coordinated programs. This paper presents and discusses a number of these issues and provides recommendations for the strategic design of such programs.

STRATEGIC DESIGN FOR INTEGRATED INTERNATIONAL MONITORING

The following are a set of general recommendations for consideration in the design of integrated large-scale environmental monitoring programs directed at evaluating environmental condition and ecosystem health over large areas. These considerations obviously do not provide comprehensive plans for the design of such programs, but are intended to propose a set of principals for establishing a strategic programmatic framework.

(1) Clearly establish the purpose or purposes for the monitoring program. Monitoring programs can be established for one or more of a number of general purposes including: (a) describing the status and trends in ambient environmental conditions, (b) detecting and characterizing existing and emerging issues or problems, (c) designing environmental management actions and programs, (d) assessing the effectiveness of regulatory and remedial programs, and (e) evaluating the status and threat during emergency situations. As the first step in the development of an integrated international monitoring program, the purpose of the program and what it can be expected to deliver need to be unambiguously established and agreed upon. It is not feasible to design a monitoring program to meet all desired purposes. Too often in the past monitoring programs have been judged failures because they were established with the expectation of achieving many different purposes and yet they have not had the resources or the design focus to deliver any of the anticipated results.

(2) Test, at known levels of confidence, unbiguously stated hypotheses concerning environmental degradation and the stresses being imposed on the environment. In addition to establishing the general purpose or purposes of a monitoring program, it is essential that there be clear definition of the specific questions that are to be answered. In consultation with resource managers and other potential users of the monitoring results, the program should establish the environmental information and the level of confidence in this information that are required. The monitoring design should then be formulated around answering testable hypotheses at known statistical levels of confidence to provide this information. The established requirements for the program can be compared to levels of environmental variability for various indicator measurements, with the final selection of the indicators to be measured and the monitoring protocols to be used determined with regard to their ability to meet data quality objectives established to fulfill these requirements.

(3) Build on coordinating and expanding existing environmental monitoring activities of public and private agencies to form integrated broad-scale monitoring networks. There are presently many environmental quality monitoring programs being conduced by agencies at various levels of government in many countries as well as by private commercial and environmental action organizations. Integrated international monitoring efforts should be built on the coordination and expansion of these ongoing efforts as much as possible. Through such coordination and integration, the additional costs for establishing international monitoring programs can be reduced, and real or apparent duplication of efforts can be avoid.

(4) Function at several spatial scales with more intensive local/regional monitoring efforts encompassed within sparser, more broad-scale networks of sites. A sparse network of measurement and observation locations should be established that cover the entire area being investigated. The sampling sites within this network

would be used primarily for measurement of a few common parameters that serve as indicators of long-term trends in environmental quality and ecosystem health. Nested within this network would be more intensive regional monitoring efforts. These would be located in areas where concerns regarding present or potential environmental degradation are focused and would often be based on coordination with existing monitoring programs. These more intensive monitoring efforts should include measurement of a set of core parameters in common with the area-wide network and thus will make it possible to place regional conditions in a broader scale perspective as well as conversely enabling the use of the regional results for assessing the broader scale conditions.

(5) Be based on integrated sampling site frameworks using both fixed position and probability-based site selection. The use of a probabilistic design for selection of sampling sites within an area leads to results that can provide statistically valid estimates of means and standard deviations of the sampled parameters within that area. The use of a deterministic or fixed station design does not allow for the development of such statistically valid area estimates. However, fixed stations can be located at sites of particular concern and at sites where it is known that the conditions required to obtain specific indicator measurements, such as the presence of a specific species or biotic community, occur. Repeated sampling at such sites is a more efficient and economical means to follow temporal trend and to measure relatively uncommon, but important, indicator properties than is probabilistic sampling. Thus, integrated international monitoring programs should utilize a combination of sampling sites selected by the two procedures. Surveys using probabilistic sampling should be conducted periodically to provide information on the general environmental conditions of commonly occurring indicator properties over large areas. However, sampling at fixed stations should also be employed to evaluate conditions at locations of special concern and to follow trends at such locations as well as to furnish information on key but less commonly occurring indicator properties such as the status of major resource populations or of threaten or endangered species.

(6) Use stratified sampling within ecologically relevant environmental components. The earth's biosphere can be subdivided into major components, such as ecoregions on land (Omernik 1987) and large marine ecosystems in the sea (Sherman 1994), within which independent driving forces such as climate, geomorphology, and geologic/water movement structure, produce an element of ecological communality and interconnectivity in comparison to surrounding areas. These components have differences in the character and sensitivity of their responses to imposed environmental stresses, as for example has been shown in evaluation of the effects of acid deposition on forests and lake and stream biota downwind of industrialized areas in western Europe and eastern North America (Irving 1991). Thus, to assure that assessment of environmental condition is valid for, not only the average conditions within a area but also across the major subdivisions of the area, it is important to stratify the sampling site locations and to assure that sampling site placement is adequate within each of the components to allow for an environmental assessment of condition.

(7) Monitor indicators of both ecological conditions and of the stresses being applied to the environment. Properties that provide integrative indications of ecosystem health should be measured throughout the program area. These properties should include indicators of the composition and abundance of major ecosystem components such as fish and macrobenthic communities in aquatic environments as well as multi-metric measures such as diver-

sity indices and production/biomass ratios. Measurement of properties that indicate levels of contaminants and other stresses being applied to ecosystems should be made in conjunction with the measurement of these health indicators. These stressor measurements will provide information for evaluating the causes and sources of observed degradation.

(8) <u>Develop consistent, program-wide procedures for data management and graphic display</u>. A large number of monitoring activities conducted by a number different public and private organizations will usually be linked to form the broad-scale integrated international monitoring networks being discussed here. The various participating programs will both furnish and receive data and results as part of their inclusion in the network. To facilitate this exchange, it is vital that they all use consistent data management procedures and formats. Also it is anticipated that the framework data base will be used by agencies at many different levels of government as well as by non-governmental organizations as the basis for producing environmental assessments of many different types. This will call for the presentation of the data on many different spatial and temporal scales and for the establishment of relationships among the properties at these various scales. Such usage of the data will be greatly facilitated by the development of a Geographic Information System (GIS) for displaying the data on various scales which can easily accessed and employed by all users of the program's data base.

(9) <u>Include a rigorous quality control and quality assurance system based on the use of performance-based evaluations of monitoring methods and data</u>. The development of valid environmental quality assessments requires the acquisition of reliable data of known precision and accuracy. These data must be spatially and temporally comparable and traceable to a common reference. Integrated international monitoring programs should include a quality assurance component to ascertain and verify the reliability of the data being obtained by the various participants. This component should include activities to provide detailed documentation of the sampling and analytical procedures employed, to develop and distribute reference materials, and to coordinate and evaluate intercomparison and exercises to intercalibrate and intercompare the results obtained by the participating programs. These intercomparisons should provide for performance-based evaluations of different methods, and should evaluate the validity and comparability of results based on such evaluations rather than on the establishment of mandatory methods and procedures.

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Perspectivas del Monitoreo Ecológico para la Evaluacion de Ecosistemas en México

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INTRODUCCION Y ANTECEDENTES

Son varias las razones que justifican analizar y profundizar sobre el monitoreo ecológico para evaluar la condición y la salud de los ecosistemas terrestres y acuáticos de México, sin embargo, de ellas destacan la biodiversidad que caracteriza al territorio mexicano, el nivel y las perspectivas de desarrollo económico y social del país y la necesidad de revertir las tendencias que actualmente tienen los procesos de deterioro de los recursos naturales.

La complejidad de este gran reto, impone la necesidad de realizar un análisis crítico de su magnitud, los recursos humanos y económicos con que se cuenta, los niveles de información requeridos, los mecanismos de coordinación para evitar la duplicidad de esfuerzos y hacer un uso óptimo de los resultados que se pretenden obtener; es decir, se requiere diseñar y operar un programa nacional de monitoreo ecológico para la evaluación de los ecosistemas terrestres y acuáticos acorde a las condiciones y necesidades de nuestro país. Adicionalmente, es necesario considerar que cada vez mas, México participa en las iniciativas de globalización, que imponen compromisos y brindan oportunidades respecto al manejo sostenible de los ecosistemas, por lo que esta importante responsabilidad deberá considerar también el contexto internacional, para desarrollar sistemas de evaluación que sean complementarios y compatibles con los de otros países, en particular los de aquellos de la región.

México es un país que no ha permanecido aislado del conocimiento y desarrollo técnico y científico sobre monitoreo ecológico, sin embargo hay que reconocer, que comparado con los esfuerzos realizados por otros países de la región y del mundo, hay mucho por hacer aún. Hasta ahora la comunicación formal y no formal entre la comunidad científica, ha producido iniciativas muy alentadoras y útiles, pero que se caracterizan por no estar integradas en un programa general y que carecen en la mayoría de los casos de la coordinación necesaria. Al igual que en muchos otros países del mundo, los técnicos y científicos de las diferentes instituciones científicas y académicas mexicanas, han venido desarrollando iniciativas específicas, muchas veces aisladas, que han estado enfocadas a la obtención de información para la solución o el manejo de problemas puntuales de algún sector productivo, que han tenido muy poco nivel de integración de la información con otros sectores.

Por otra parte, dichas iniciativas han estado dirigidas principalmente hacia la evaluación de los diferentes tipos de recursos naturales, como partes aisladas de los ecosistemas, en ocasiones sin mecanismos de periodicidad e integración, que permitan un sistema de información que de una imagen clara de la condición en que se encuentra algún ecosistema en lo particular o un conjunto de ellos en lo general.

No obstante que las instituciones académicas y científicas mexicanas cuentan con niveles competitivos, no existen aún programas de formación de recursos humanos específicos sobre monitoreo ecológico y los proyectos de investigación sobre la materia son incipientes, reconociendo que se requieren grupos multidisciplinarios e interinstitucionales para su desarrollo.

LA COMPLEJIDAD DE LOS SISTEMAS ECOLOGICOS, ECONOMICOS Y SOCIALES

México es un país de grandes contrastes ecológicos, económicos y sociales, lo que imprime un importante grado de complejidad al monitoreo ecológico. En el

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medio físico, el origen geológico y la geomorfología, dan como resultado un auténtico mosaico de suelos y geoformas; su posición geográfica en el planeta, provocan una gran variación climática; y ambas circunstancia, sumadas a a ser centro de origen de muchas especies animales y vegetales, lo tipifican como uno de los nichos de mayor diversidad biológica del mundo. Son varios los géneros de animales y vegetales, que tienen el mayor número de especies en el territorio mexicano, tal es el caso de los reptiles, los pinos, las cactáceas y los encinos, entre otras. La combinación de latitudes y altitudes y las corrientes migratorias, influyen significativamente para que se tenga una gran biodiversidad.

Poco mas del la mitad del territorio nacional está constituido por zonas áridas y semiáridas, que contrastan con ecosistemas templados y fríos de montaña y que se hacen profundamente complejos en las regiones del trópico, tanto húmedo como seco.

En cuento a sus condiciones económicas y sociales, el país se significa por profundas raíces y costumbres indígenas, que atraviesan aún por un proceso de mestizaje continuo que la nación ha vivido durante los últimos cinco siglos, prevaleciendo en la actualidad comunidades indígenas casi puras, que se debaten ante los impactos de la modernidad y el desarrollo.

México cuenta con grandes concentraciones humanas que constituyen megalópolis complejas y difíciles de administrar como la gran Ciudad de México, Guadalajara o Monterey, que contrastan con una gran dispersión de poblados muy pequeños y aislados ubicados en las serranías de Guerrero, Oaxaca y Chiapas; o bien pueblos casi fantasmas con actividades marcadamente estacionales de sus zonas áridas y semiáridas.

Esta gran diversidad ecológica, económica y social, origina sistemas de producción que en ocasiones son altamente tecnificados, como los de las planicies costeras del noroeste del país, en que se producen cosechas equiparables a las de los países con los mas altos rendimientos por hectárea, o bien aquellos que son apenas para la subsistencia de los habitantes del medio rural en el semidesierto de las planicies centrales, en las que año con año el productor agrícola se enfrenta a los caprichos climáticos en espera de un temporal con lluvias aleatorias que apenas le permitirán cosechar unos cuantos kilogramos para su autocinsumo.

En cuanto a la presencia y distribución del agua, elemento vital para las actividades humanas, los contrastes son también muy marcados, tanto desde el punto de vista estacional, con bastos territorios en que se suceden amplios períodos de sequía que cambian bruscamente con precipitaciones pluviales torrenciales, característica frecuente en las planicies del trópico seco de la vertiente del Océano Pacífico; como por la presencia de áreas con precipitaciones pluviales y acuíferos abundantes de mas de 3,000 milímetros anuales de lluvia.

LOS RECURSOS PARA REALIZAR EL MONITOREO ECOLOGICO

México cuenta con instituciones públicas y privadas capaces de llevar a cabo las actividades de monitoreo ecológico. A nuestro juicio, los recursos humanos técnicos y científicos de las instituciones técnicas, académicas y científicas con que se cuenta, serían suficientes para este importante programa. Además hay un importante acerbo de conocimientos y experiencias científicos y tecnológicos, que aunados a la infraestructura disponible, permitirían desarrollar un programa bien coordinado de monitoreo ecológico.

En la actualidad los recursos económicos que permitieran un programa de monitoreo con la necesaria continuidad y capacidad operativa, pueden significar una de las limitantes importantes. Las prioridades presupuestales están enfocadas a la solución de otros problemas urgentes e inmediatos, por lo que la obtención de recursos para estos fines, estaría condicionada a una muy amplia y profunda justificación, que pueda transmitir a los mas altos niveles de toma de decisiones, la importancia de contar con información de calidad y en forma continua para el manejo sostenible de los ecosistemas, destacando claramente los impactos económicos, ecológicos y sociales que puede representar su uso adecuado.

Un reto particular que deberá explorarse, es el relativo al desarrollo de tecnologías y metodologías de bajo costo, que permitan niveles de información confiables y que a la vez puedan transferirse ampliamente para contar con una red de monitoreo bien consolidada.

Los recursos actuales de informática y sistemas, caracterizados por una vertiginosa carrera de innovaciones en equipos y sistemas, sin duda brindan excelentes oportunidades para la disponibilidad de la información, sin embargo, hay que considerar que de acuerdo a las posibilidades y recursos de cada país, el mejor sistema es el que permita contar con la información en el nivel de calidad y al costo adecuado, por lo que mas que sumirse en la complejidad de los equipos y sus programas informáticos, debe diseñarse un sistema que si funcione para los fines que fue creado.

UNA INICIATIVA ACORDE A LAS CONDICIONES ACTUALES DEL PAIS

Sin duda que los programas y sus resultados alcanzados por otros países del mundo en materia de monitoreo ecológico, significan un importante reto y compromiso para nuestro país, en especial cuando se trata de nuestros principales socios comerciales, con los que se han logrado importantes acuerdos en materia ambiental. Por otra parte, las políticas públicas mexicanas en la actualidad, hacen un reconocimiento y dan una prioridad especial al manejo sostenible de los ecosistemas, de tal forma que se frenen y reviertan los procesos de deterioro de los recursos y mas aún, que dicha base de recursos se constituya en verdadera palanca de desarrollo de la nación.

No obstante lo anterior, es necesario reconocer que México deberá incorporarse a los procesos de monitoreo ecológico en una forma paulatina, coordinada, eficiente y eficaz. Es necesario considerar que las condiciones económicas y sociales actuales, así como la complejidad que representa el reto de establecer un buen programa de monitoreo ecológico, acorde a las condiciones de los ecosistemas, deberá llevarse a cabo en forma paulatina, engranando cuidadosamente los diferentes niveles en el tiempo y en el espacio que permitan contar con información útil y aplicable. Quizá en las primeras etapas del programa, será necesario invertir importantes recursos en organización y capacitación, mas que en la operación. Para el establecimiento de las redes de monitoreo, habrá que debatir sobre la conveniencia de una gran cobertura sacrificando precisión y detalles o bien, el desarrollo de un programa que atienda sitios con problemas específicos que requieran ser evaluados para su protección, manejo y conservación. O bien, establecer una red amplia de monitoreo, que paulatinamente pueda hacerse mas completa en su cobertura y al mismo tiempo, monitorear sitios específicos.

Lo cierto es que México deberá incorporarse bien pronto a una iniciativa coordinada y concertada de monitoreo ecológico y las experiencias positivas y negativas que se han tenido en otros países pueden ser de gran utilidad para diseñar un sistema acorde a nuestras necesidades.

EVITAR LA DUPLICIDAD DE ESFUERZOS

En un país de programas y recursos limitados, resulta de la mayor importancia evitar la duplicidad de esfuerzos y lograr los mejores esquemas de coordinación para el desarrollo de una red de monitoreo ecológico funcional. Dicha coordinación implica que los diferentes niveles de gobierno y los distintos sectores, conozcan, acepten y participen en el programa, cada quien con las atribuciones, responsabilidades y beneficios que deba tener.

En particular, consideramos que la iniciativa y la coordinación del programa deberá partir del Gobierno Federal, con el concurso de las instituciones técnicas, académicas y científicas, en el ámbito de sus responsabilidades y creando, si fuera necesario, nuevos esquemas de coordinación que permitan la operación eficiente del programa de monitoreo ecológico.

Respetando las atribuciones y responsabilidades de las diferentes instituciones y organismos, se considera conveniente la continua evaluación de congruencia entre los programas y proyectos técnicos y científicos que se llevan a cabo sobre monitoreo ecológico, de tal forma que las instituciones puedan identificar aquellos esfuerzos que se duplican, los que se complementan o bien aquellos que deban ser reforzados.

PARA QUE SE REQUIERE UN PROGRAMA DE MONITOREO ECOLOGICO Y QUIENES SON LOS USUARIOS

El monitoreo ecológico sin duda está orientado a producir información y resultados para que sean usados por los diferentes niveles de toma de decisiones que son responsables de la administración de los

recursos naturales y del desarrollo social y económico. Los resultados que produce esta importante actividad, permiten orientar el desarrollo de programas para la conservación, aprovechamiento y fomento de los diferentes tipos de ecosistemas, que aseguren elevar el nivel de bienestar de la sociedad. Sin este tipo de información, la administración de los diferentes componentes de los ecosistemas puede estar sujeta a contradicciones y controversias. La información calificada sobre la condición general y la salud de los ecosistemas orienta a los que toman decisiones a obtener resultados de una mayor equidad social, económica y ecológica.

Los programas de desarrollo social y económico, en la actualidad deben ser evaluados cada vez con mayor precisión respecto a sus implicaciones ecológicas y solamente mediante el conocimiento continuo e integral de los ecosistemas que involucran, será factible considerar su desarrollo sostenible.

Son usuarios directos de los programas de monitoreo ecológico, los diferentes niveles gubernamentales de toma de decisiones y administración de los recursos naturales, así como también aquellos de los sectores relacionados de la economía. Los ususarios indirectos son los dueños y poseedores de los recursos y la sociedad en general, ya que las decisiones que se adopten basadas en la información obtenida, a la larga tendrán sobre de ellos un impacto positivo.

En la medida que los diferentes niveles de la sociedad conozcan y se apropien esta información, la continuidad de los programas de monitoreo ecológico será asegurada. Bajo las condiciones actuales de México, el programa de monitoreo ecológico deberá producir información y resultados útiles que tengan una demanda específica, de lo contrario, la factibilidad de contar con una auténtica red de monitoreo ecológico se ve muy limitada.

La comunidad científica también es un usuario importante de los resultados e información de un programa de monitoreo ecológico, ya que le permite orientar sus proyectos de investigación hacia aquellos huecos de información y metodologías que tengan deficiencias. Asimismo, es factible orientar la formación de recursos humanos especializados para el monitoreo ecológico a través de los programas académicos de las instituciones de enseñanza.

INCORPORACION DE MEXICO A LAS INICIATIVAS INTERNACIONALES

Los ecosistemas no obedecen límites geopolíticos y frecuentemente existen en forma continua rebasando las fronteras de países y razas. por otra parte, los principios de soberanía y autodeterminación de las naciones, pueden provocar puntos de vista y diferencias marcadas con respecto a su administración.

Ambas premisas al parecer contradictorias, deben ser respetadas, la primera, como un principio lógico de la naturaleza, y la segunda como el punto de partida para el respeto y buen entendimiento entre las naciones. Aprovechando ambas, es factible considerar que las tareas de monitoreo ecológico de cada país, pueden ser apoyadas, asesoradas y fortalecidas por las de otros países. En el contexto internacional actual, ningún país puede aislarse del desarrollo científico y tecnológico, sobre todo el de sus vecinos y socios comerciales en una misma región. México puede esperar importantes aportaciones en cuento a las experiencias y conocimientos sobre monitoreo ecológico de los Estados Unidos y de Canadá, tanto en la transferencia de conocimientos y tecnologías, como en la integración de redes de información regional que permitan una visión de conjunto de la región.

En este proceso, sin embargo, es necesario que no se pierdan de vista las diferentes escalas y niveles de desarrollo, que imprimen características específicas para cada país. Los esfuerzos deberán estar orientados hacia el desarrollo de sistemas de monitoreo que sean compatibles y complementarios, respetando en todo momento la capacidad y los procesos de desarrollo y evolución que en esta materia tienen amplias perspectivas en la región.

Por otra parte, es necesario desarrollar iniciativas conjuntas que permitan a los países de América del Norte, contar con información de calidad y en cantidad suficientes para integrarla con aquella que ya obtienen otras regiones del mundo y poder así, desarrollar iniciativas regionales y mundiales en beneficio de la humanidad.

SUBJECT II: EXPERT OVERVIEW ON MONITORING FOR ECOLOGICAL ASSESSMENT

Presentations focused on the problems, needs and opportunities for monitoring for assessment, in particular, those arising during attempts at assessment across ecosystem resource groups. Within a trans-ecosystem perspective, invited experts from Canada, United States, and Mexico addressed such issues as the nature and impact of client and stakeholder needs and expectations for information; the nature of information uncertainty and conflicting estimates and how they can best be resolved; existing opportunities for common monitoring and assessment philosophies or approaches; the nature of effective strategies for implementing monitoring and research activities; the nature of funding and organizational constraints and how they can be managed; the need for and feasibility of creating and promoting partnerships, networking, cooperation and collaboration between institutions, and across agencies and countries; and the nature of future challenges to and perspectives on monitoring for ecological assessment of ecological systems.

Ecological Assessment in Canada

Harvey Shear, Ph.D.[1]

Abstract.—Assessment and monitoring of ecological structure and function are carried out by a number of government and non-government agencies in Canada. Ecosystems monitored include terrestrial and aquatic (both freshwater and marine) in many of Canada's major ecozones. The parameters monitored, frequency of sampling, degree of data analysis, and the extent of integration of various data sets, is highly variable. This is a direct result of, at least, the individual objectives of the monitoring programs, the resources available for monitoring and analysis of data, and the mandates of the agencies involved. This paper will explore some of the reasons for these differences and possible ways of achieving a degree of commonality of approach where desirable and feasible.

INTRODUCTION

In Canada, there are many monitoring activities carried out for a variety of reasons. Some reasons are purely scientific, some are regulatory, and others are political. Monitoring occurs in many of Canada's 15 terrestrial ecozones, including the freshwater rivers and lakes, as well as its 5 marine ecozones including the Great Lakes (see figures 1 and 2).

As resources become ever more scarce, and questions are asked about the utility of long term monitoring and concurrent research, it is incumbent upon scientists and managers to refine their monitoring programs, and to define better the goals, objectives and products of such monitoring. One needs to examine carefully the possible partnerships that can be promoted, the interjurisdictional cooperation that can be encouraged and developed, as well as the very nature of the information being generated.

This paper will examine several of these issues and relate them to actual **monitoring being carried out in Canada.**

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DEFINITIONS

In order to understand the concepts being discussed, it is necessary to provide some definitions. While these definitions may be at variance with those accepted elsewhere, it does not matter, as long as the reader understands what is meant be each term in this paper.

Monitoring

The routine collection, analysis and interpretation of biological, physical and chemical information at a defined site over a defined time period, with a defined frequency of collection.

Ecological Research

The investigation of the structure and function of ecosystems to understand the forces that drive these systems, and to understand the effects of natural and human-induced stresses on these systems.

Ecological Experimentation

The manipulation of ecosystems under controlled conditions to study responses to stress.

Legend

1. Tundra Cordillera
2. Boreal Cordillera
3. Pacific Maritime
4. Montane Cordillera
5. Boreal Plains
6. Taiga Plains
7. Prairie
8. Taiga Shield
9. Boreal Shield
10. Hudson Plains
11. Mixed Wood Plains
12. Atlantic Maritime
13. Southern Arctic
14. Northern Arctic
15. Arctic Cordillera

Figure 1. The 15 terrestrial ecozones of Canada (from Wiken 1986).

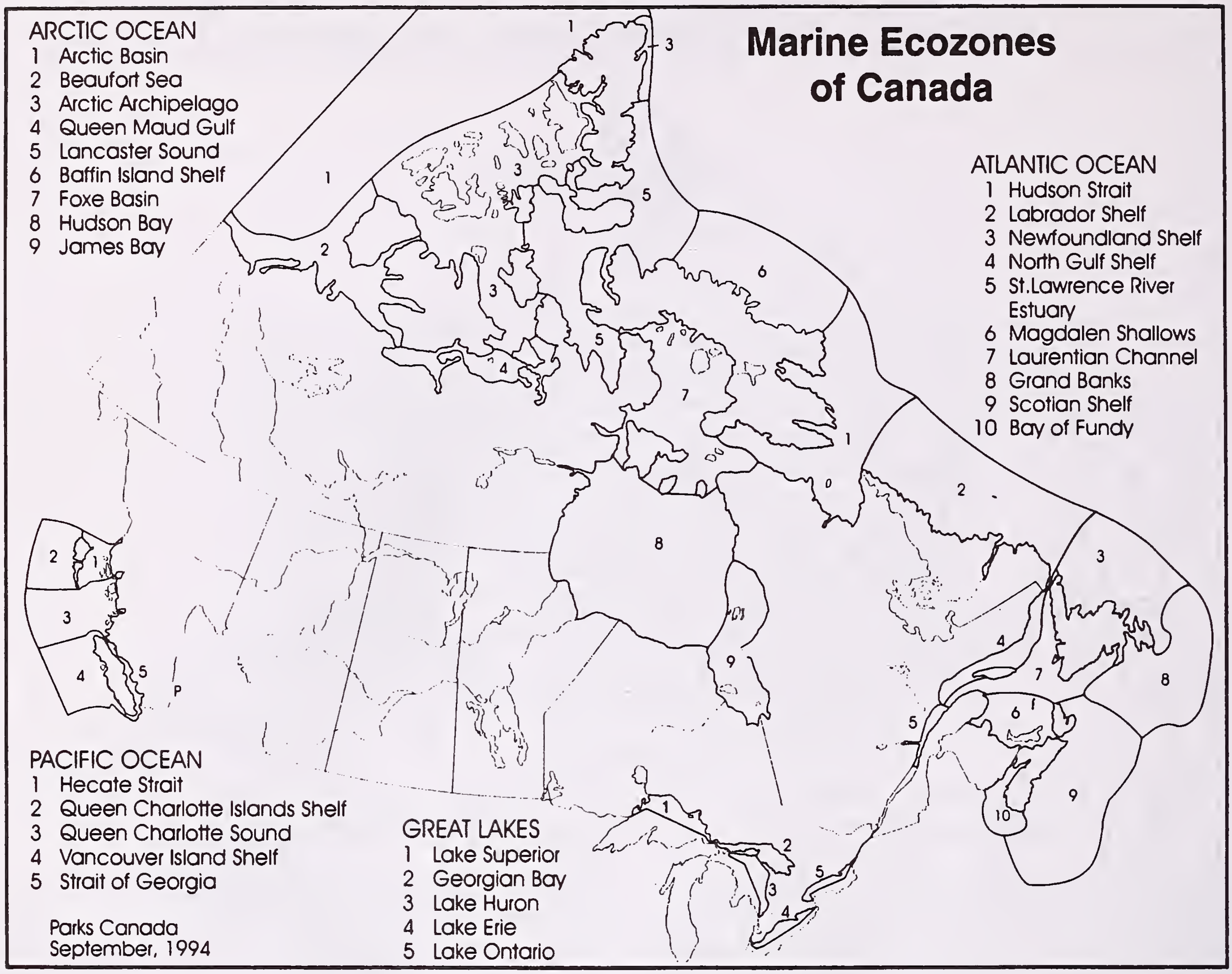


Figure 2. Marine Ecozones of Canada (Environment Canda, 1995).

Ecological Integrity

Attributes of an ecosystem that include resilience to environmental change, relatively high biodiversity, relative complexity both structurally and functionally, and relative stability over long time periods.

Assessment

Assessment used in this paper means the analysis and interpretation of the data collected from monitoring and/or research, to provide advice on measures that environmental agencies need to take to prevent or mitigate stresses on ecosystems.

PURPOSE OF ECOLOGICAL MONITORING

The Canadian Ecological Monitoring and Assessment Network defines the purpose of ecological monitoring, in its simplest terms, as the understanding of *what is changing, and why.* A corollary to this is to anticipate and prevent the loss of ecological integrity.

Ecological monitoring is carried out for a number of reasons, all of which, whether explicitly, or implicitly are geared towards the purpose. At least three, and perhaps other reasons have been put forward for monitoring:

Scientific- When resources were readily available, scientific curiosity greatly influenced some monitoring programs. Monitoring design was driven by the need to know as much as possible about an ecosystem, whether or not the information would ever be used. The Great Lakes International Surveillance Plan is a case in point. The Plan was all encompassing in terms of what was monitored (all media), was very extensive in its spatial scale (whole lake sampling), and fairly ambitious in its temporal scale, including several whole lake cruises per year.

Regulatory Requirements- There is a legislated requirement to collect environmental information for purposes of compliance monitoring. This information may be used for negotiation of voluntary compliance schedules, or for prosecution under appropriate environmental legislation. This type of monitoring is usually very focussed on the specific requirements of legislation, yet it can generate useful information on ecological trends and processes.

Political Necessity- Although every ecological monitoring program has the collection and interpretation of scientific information as a foundation, there are instances where such collection is driven by political needs. The acid rain program in North America is a case in point. Canada had accumulated evidence in the late 1970s and early 80s that acidic precipitation caused by emissions of SO_4 was having adverse effects on the biota of freshwater lakes and rivers in eastern Canada, in those areas lacking sufficient buffering capacity to neutralize the acid. The United States was the largest source of SO4 to Canada, but the government of the US, after 1980, would not accept the arguments being put forward for controls on emissions of sulphur oxides. Canada had to develop an extensive acid rain monitoring network, and carry out definitive experiments at the Experimental Lakes Area in NW Ontario, before the US finally accepted the overwhelming evidence that acid rain causes negative, unacceptable impacts in freshwater bodies, and that much of the source of the acidity was the U.S. This monitoring and research led directly to the Canada-US Air Quality Accord.

In addition to these three driving forces, there are others that are summarized in table 1 (Anderson et al. 1992).

INDICATORS

Ecological monitoring is not carried out solely for the benefit of scientists. Monitoring must meet the needs of policy and law, both domestic and international, in a way that is usable to policy and lawmakers as well as to the public at large. The target audience for monitoring information , that is policy and law makers, may not be scientists. It is therefore essential to have a clear, understandable set of ecological indicators that can relate either to ecological stressors, or to conditions of ecological health. These indicators must, of course, be based on sound science. One may argue at the use of indicators that are not masked in scientific language. If scientists do not develop and promote such indicators, however, there will be little support for monitoring programs, since very few people will understand what the monitoring program has produced, and what is its utility to society.

Figure 3 gives a general overview of the kinds of stressors impacting on human and ecosystem health (SOLEC, 1995). The selection of appropriate indicators to interpret the effects of these stressors depends very much on the ecological issues being considered. There are at least three types of indicators- **stress indicators** (eg. levels of emissions of CO_2); **exposure indicators** (eg. levels of contaminants in fish and wildlife); and **response indictors** (eg. reproductive impairment of wildlife) (Freedman et al. 1993). The selection of appropriate temporal and spatial scales is also important, and ranges from seconds to centuries for the temporal scale and individual cells to entire landscapes for the spatial scale. An inappropriate selection of indicators can prove costly both financially, and in terms of credibility of the monitoring program. If a government needs a national assessment of, say, mercury in the environment, selection of a subcellular response indicator for mercury will not be adequate.

Table 1. Monitoring and assessment under five generalized styles of environmental mangement.

	FRONTIER ECONOMICS	RESOURCE MANAGEMENT	SUSTAINABLE DEVELOPMENT	SELECTIVE ENVIRON-MENTALISM	DEEP ENVIRON-MENTALISM
Motivation	what is there?	what is there? what is changing?	what is there? what is changing? why is it changing?	what is there? what is changing?	what is there?
	facilitate resource exploitation	conserve renewable resources	ensure ecological security	protect environment	curiosity, discovery
	single purpose	single or multi-purpose	multipurpose	single or multi-purpose	single purpose
Scope	resource-based	resource-based	systems-oriented	nature-based	nature-based
	narrowly focused	multidisciplinary	fully integrated	multidisciplinary	narrowly focused
	selected variables)	selected variables	multivariate	selected variable(s)	selected variable(s)
	single medium	selected media	multimedia	selected media	single medium
Partnerships	none, or few	limited	all relevant interests	limited	none, or few
Methodology	inventories, surveys concerned with 'how much,' monetary potential	compliance and regulatory monitoring	comprehensive, integrated monitoring	effects monitoring	natural histories, inventories, rankings, classifications
		case studies on resource use or development	comprehensive ecosystem assessments	case studies an specific environmental concerns	
Time frame	short-term	short-term	long-term	short-term	short-term

In Canada, the State of the Environment Directorate has produced a number of "user friendly" indicators, ranging from fisheries population indicators to greenhouse gas indicators (SOER).

In the Great Lakes context, indicators were prepared for the first State of the Lakes Ecosystem Conference (SOLEC, 1995). Canada and the United States co-hosted this conference for selected decision makers in the Great Lakes basin. An assessment was made of the state of health of the aquatic community, habitat and human health, as well as the state of the stressors on the ecosystem (nutrients, toxic chemicals, and the economy). These indicators are shown in Table 2. The ratings were very simple, yet very effective in conveying the interpretation of a wealth of monitoring data, collected over the past 25 years.

WATERSHED OR ECOZONE - WHAT SHOULD BE MONITORED?

In Canada, the entire land mass is divided into 15 ecozones (see figure 1). Given the size of Canada, these zones are obviously very large. Does it make sense to monitor on such a large scale? From the standpoint of aquatic resources that inhabit these ecozones, the watersheds of lakes and rivers form a much more discrete boundary between ecosystems. For example, in British Columbia, the province is divided into 3 ecozones, all three of which cross the watershed divide between the Pacific and Arctic Oceans. In terms of fishery resources, the Pacific/Arctic divide is the significant boundary. How then does one monitor ecological changes in B.C.? The

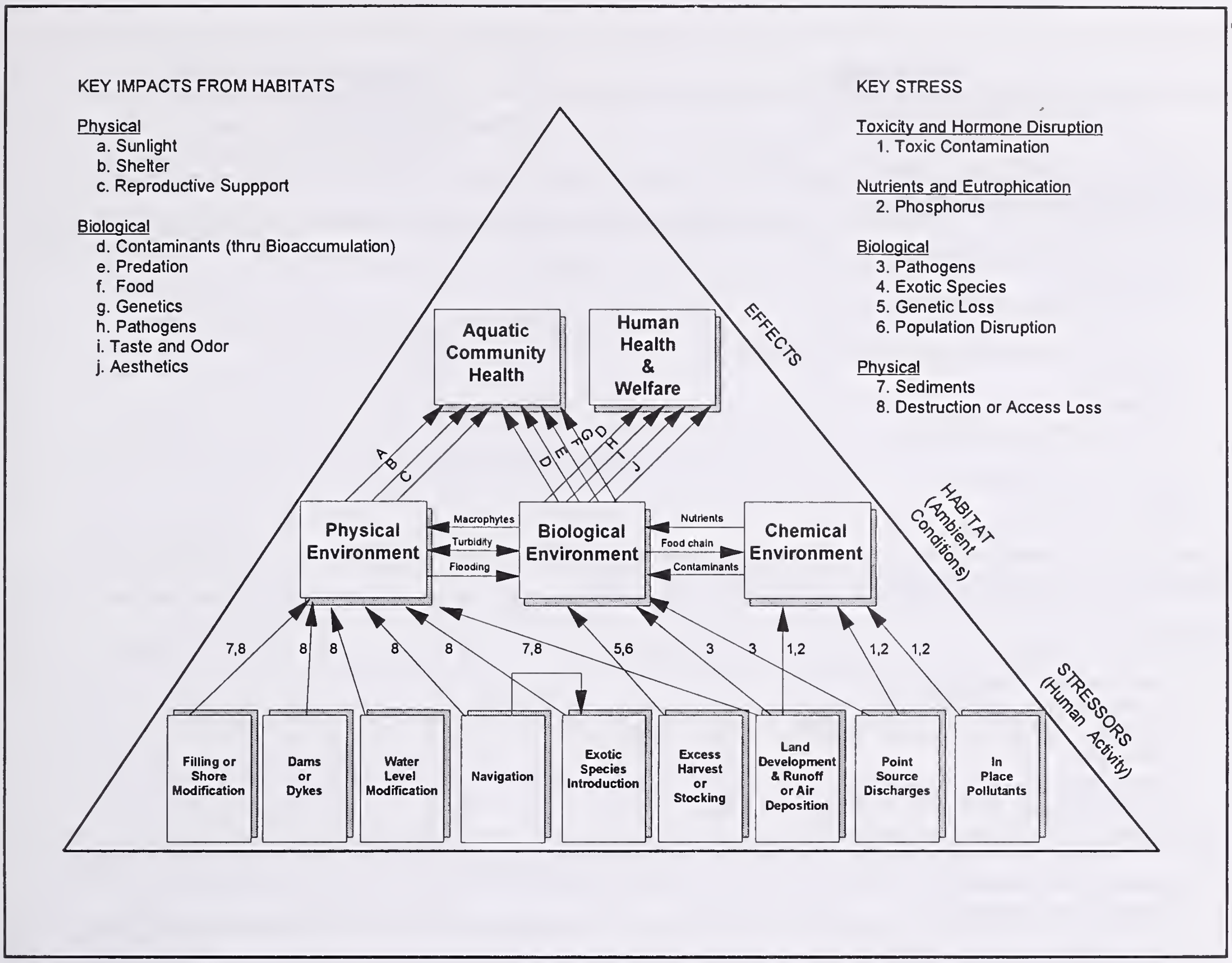


Figure 3. Primary ecosystem stressors and effects.

answer depends very much on the questions being asked by management agencies. If the concern is over fisheries, then the watershed boundary seems the logical choice. If there are broader ecological impacts, especially of a terrestrial nature, being examined, then the ecozone is the appropriate scale. The important point is to determine what needs to be monitored, and to select the geographic scale that will provide the answers.

INFORMATION UNCERTAINTY

When ones analyses data from long term monitoring programs, there will be situations where the information is incomplete, or where the information from one element of the program contradicts other information. A case in point is illustrated in figures 4 and 5. This figure shows the trends in contaminants in a fish and a wildlife species (lake trout and herring gull) in the Great Lakes basin. It is apparent that concentrations of these selected contaminants decreased dramatically from the early 1970s to the mid to late 1980s, but that these concentrations have not shown any further decrease for the past several years, and in fact show a slight increase.

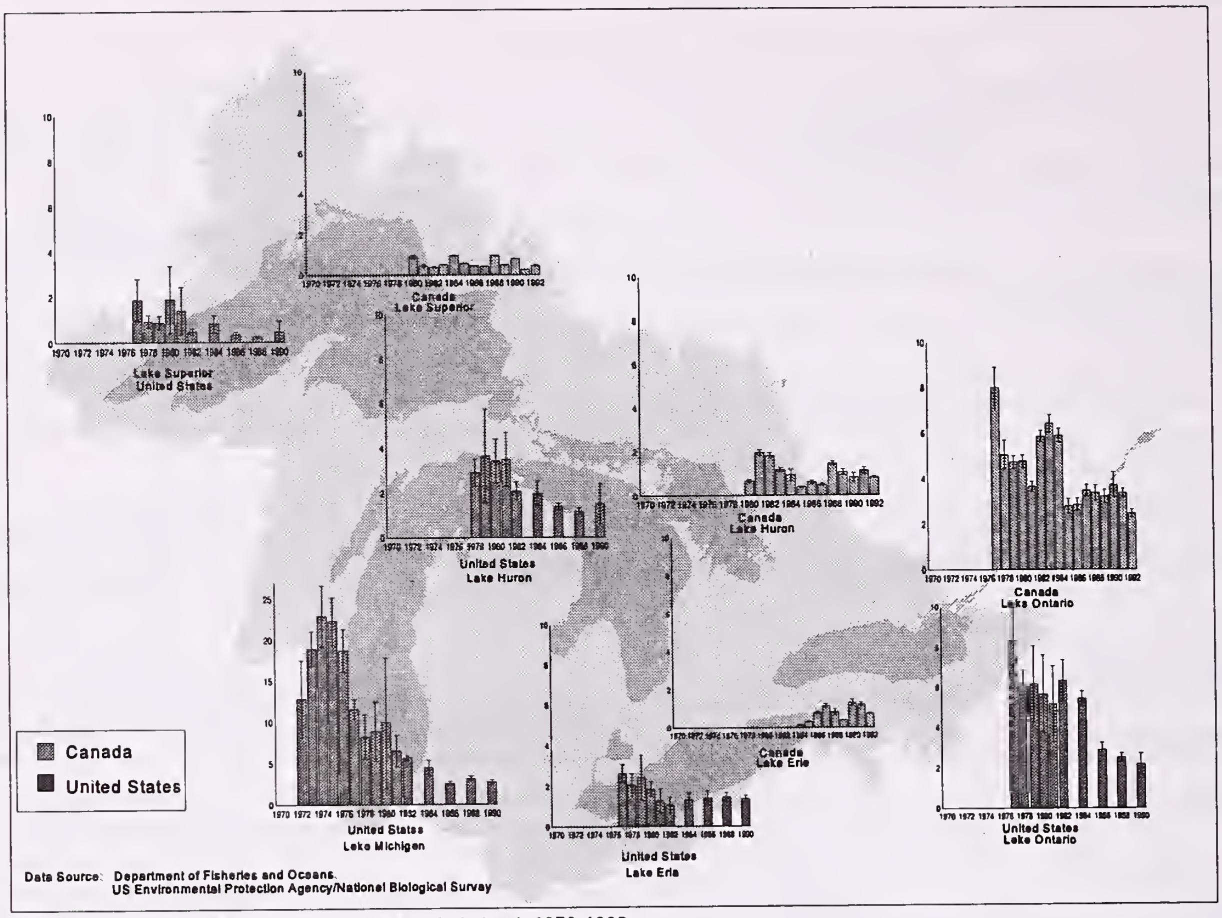
We know from other sources, such as industrial and municipal effluent and emissions monitoring, that the amounts of these compounds being discharged have continued to decline. How can one explain this apparent contradiction? Long range transport of these chemicals from sources outside the Great Lakes Basin is well documented, and can account for some of the continuing input, as can recycling from contaminated sediments. These sources alone, however, can not explain the trends shown in figures 4 and 5. One hypothesis put forward (SOLEC, 1995) suggests that a change in the food chain may be the culprit. The Great Lakes have undergone exten-

Table 2. Primary indicators of ecosystem health.

INDICATORS	STATUS OF INDICATORS			
	Poor	Mixed/ Deteriorating	Mixed/ Improving	Good/ Restored
STATE OF AQUATIC COMMUNITIES				
1. Native Species Loss (# of native species)				
Lake Superior				✔
Lakes Huron, Michigan, Erie & Ontario			✔	
2. Ecosystem Imbalance (Lake Trout Dichotomous Key)				
Lake Superior				✔
Lake Huron			✔	
Lakes Michigan, Erie & Ontario	✔			
3. Reproductive Impairment				
Effects - all Lakes			✔	
Body burdens - all Lakes			✔	
HUMAN HEALTH AND ENVIRONMENTAL CONTAMINANT RISKS				
Overall state			✔	
1. Air/water/soil/sediment contamination	-	-	-	-
• contamination trends (O_3, SO_4, dust)				
• hospital admission and death rates for respiratory illness (eg. asthma)				
• beach closings				
• infectious diseases related to recreational uses				
• atmospheric and total radioactivity				
2. Fish consumption advisories	-	-	-	-
• contaminant loadings				
3. Human contaminant body burdens	-	-	-	-
4. Measurements of health status/health effects	-	-	-	-
• birth defects and cancer				
• longevity				
• children's body weight/development				
STATE OF AQUATIC HABITAT AND WETLANDS				
1. Loss in habitat/wetlands quality & quantity	✔			
U.S. - Michigan Survey	✔			
- other states	✔			
Ontario - CWS coastal wetlands				
- Brook trout stream habitat (Upper Lakes)				✔
- Brook trout stream habitat (Lower Lakes)	✔			
2. Encroachment/development basinwide	✔			
3. Gains in habitat/wetlands quality & quantity				
• areas protected under the North American Wildfowl Management Plan				✔
• net effect	✔			

Table 2 (continued). Primary indicators of ecosystem health.

INDICATORS	STATUS OF INDICATORS			
	Poor	Mixed/ Deteriorating	Mixed/ Improving	Good/ Restored
NUTRIENT STRESSES				
1. Total phosphorus loads • targets achieved in 4 of 5 Lakes (1991)				✔
2. Total phosphorus intake concentrations • objectives achieved in all Lakes (1991)				✔
3. Lake Erie dissolved oxygen (central basin hypolimnion)			✔	
4. Chlorophyll a (as indicator of nuisance algal growth) in Lower Lakes				✔
CONTAMINANT STRESSES				
1. Loadings			✔	
2. Residue in fish			✔	
3. Residue in birds (herring gulls)			✔	
4. Body burdens - all Lakes			✔	
ECONOMIC STRESSES AND MITIGATING ACTIVITY				
1. Employment (manufacturing & other sectors)		✔		
2. Infrastructure investment (public & private sectors)	✔			
3. Research & development (measures of technological innovation)		✔		
4. Land-use and reuse changes (loss of agricultural land and urban development)	✔			
5. Population growth & stability (compared to other regions)		✔		
6. Pollution prevention (expenditures & results - loadings/emissions/discharges)			✔	
7. Personal income (statistics)		✔		
8. Adoption of stewardship approach (public & private sectors)			✔	
9. Water conservation (industry & per capita)			✔	
10. Energy use (per capita)			✔	



PCB levels (µg/g wet weight±S.E.) in aged 4+ whole trout, 1970-1992.

* PCB levels (µg/g wet weight±S.D.) in whole lake trout (composites, 600-700 mm T.L.), 1977-1992.
Lake Erie (US Data) obtained with Walleye.

Figure 4. Total PCB levels in lake Trout, 1970-1992.

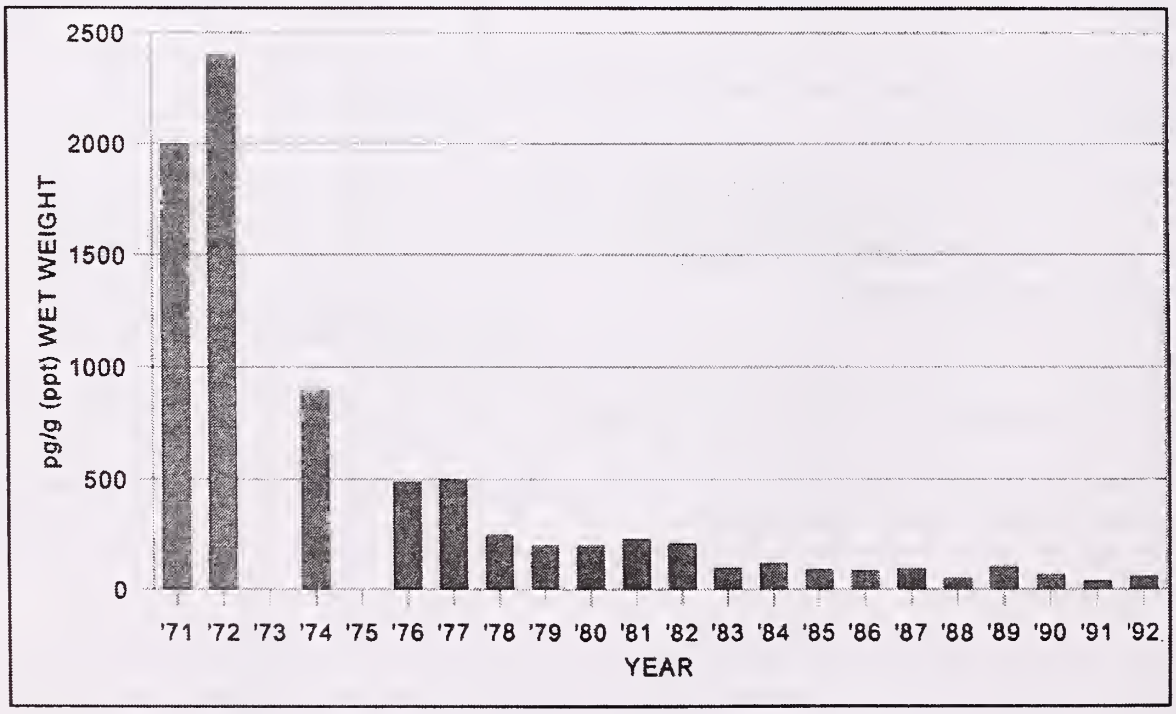


Figure 5. Dioxin (2,3,7,8-tetrachloro-di-benzo-dioxin) concentration in herring gull eggs from eastern lake Ontario, 1971-1992.

sive biological changes over the past four centuries, and particularly in the 20th century. The invasion of the Lakes by non-indigenous species has had profound effects on the ecosystem. The arrival of zebra mussels *(Dressina polymorpha)* in the late 1980s has altered the food web of the Lakes. It is possible that top predator fish, and colonial nesting birds are now feeding on different organisms, ones that may be more contaminated with persistent toxic chemicals, than the previous food supply. This could explain the trends referred to earlier. Clearly there is scope for intensive monitoring and research to shed light on this question.

Yet another apparent anomaly is the resurgence of cormorant populations around the Great Lakes (figure 6), at the very time when persistent toxic chemicals were having an effect on the reproduction of other species such as herring gulls and bald eagles. Again how does one explain this apparent contradiction? One must look at other factors such as habitat and food availability to explain these population trends. Clearly understanding the population dynamics of these birds requires monitoring all components of their life cycle, and not merely the chemicals to which they are exposed. In addition to these kinds of uncertainty, monitoring experts face data incompatibility, the result of many organizations collecting information at a particular site with little or no standardization of the parameters being examined.

THE NEED FOR COOPERATION

The continuation of existing, or the establishment of new monitoring programs requires the cooperation of all agencies with an interest in the site in question. The reasons for this involve the complexity of ecosystems, the need for data compatibility, data interpretation, and cost savings. It is no longer feasible to have several organizations collecting samples, analysing them, interpreting the data and reporting the information on separate components of the ecosystem, without close cooperation.

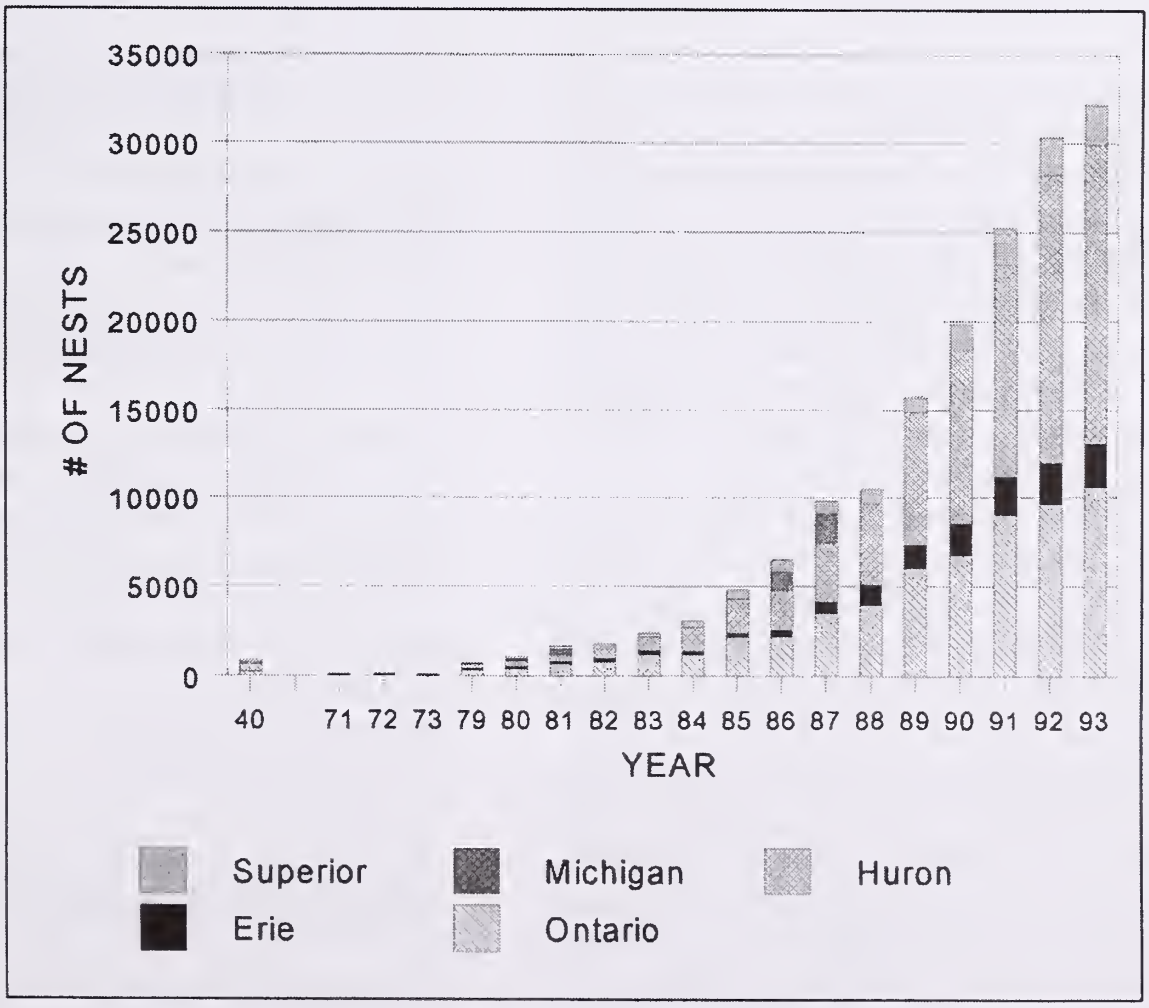


Figure 6. Double-crested cormorant populations in the Great Lake Basin.

In Canada, we have taken the ecosystem approach to monitoring. The Ecological Assessment and Monitoring Network is building a confederation of agencies across the country. The Network will ultimately have monitoring and assessment nodes in each ecozone of the country. For example, in the Mixed Wood Plain ecozone, spanning the lower Great Lakes and the St. Lawrence Valley, there are many individual sites where agencies have been monitoring for many years, or where new monitoring activities are planned. Each agency, and these include governments, non-government groups and universities, has its own objectives for its site. These may include the study of the impact of agricultural practices on adjacent undisturbed ecosystems, the impact of human activity on river ecology, status of wetlands, monitoring air borne contaminants, health of forested ecosystems, or amphibian population dynamics, as examples. When one looks at the ecozone level, however, it is clear that each of these studies could contribute to a better understanding of the changing ecology of that ecozone.

Organizational constraints, however, often impede effective collaboration. The EMAN is encouraging the collaboration of these various activities in a way that will ensure the survival of this monitoring. Project leaders from each site in the ecozone will be providing ecological information to the EMAN on their sites. This approach will aid in data interpretation, since a common information base will be available to all project leaders. The principal investigators will meet periodically to share information, "network", form new working relationships, and refine their monitoring program as required. Through the sharing of information, there will be opportunities for cost savings by avoiding duplication.

The role of universities in monitoring is an area where there is fertile ground for collaborative work, but where the shorter term needs of universities are some times at odds with the longer term needs of government. The EMAN is encouraging the universities to join the network. There are many universities across Canada that maintain field sites for research. The universities carry out predominantly process research, as opposed to long term monitoring. This information is invaluable, however, in interpreting monitoring data. Modest amounts of funding support to universities to augment their grants, can yield information that would be very costly to obtain by a government agency starting a new research project. EMAN is asking universities to provide information on their long term research sites, to integrate them into the network. It should be possible to satisfy the objectives of universities (academic inquiry, graduate student training, primary literature publication) and those of government (long term data sets aimed at answering specific policy/regulatory questions) through the cooperative design of monitoring/research programs, funding of graduate students, joint publications, and participation at workshops.

CONCLUSIONS

The future of ecological monitoring in Canada depends on cooperation. The time when each agency could set up its own monitoring network is past. Funding constraints at all levels of government preclude such an approach. The key to maintaining long term monitoring lies in selecting key sites of intensive monitoring that represent either undisturbed (reference site) or disturbed sites in the major ecozones, and from which trends can be extrapolated on an extensive basis. One must ensure that the principal investigators in each site know what is being investigated at other sites, and must work towards better sampling regimes, data analysis, data interpretation and reporting. The monitoring program needs strong leadership to maintain the information flow, to identify areas of overlap and duplication, and to identify gaps in information.

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Monitoring for Ecological Assessment

G. Bruce Wiersma[1] and Dale A. Bruns[2]

Abstract.—Many studies and groups of scientists have tried to define a workable system for the assessment of terrestrial ecosystems. Ted Munn was one of the pioneers in this area. Much of what Munn wrote over twenty years ago is still valid today. This paper reviews Munn's work, more recent efforts such as that by Heal and others and other cited works relative to the development of ecological terrestrial monitoring systems. In particular this paper highlights the use and need for conceptual models in the design of these monitoring efforts and discusses existing ecological monitoring networks. Ecological monitoring parameters, issues of scale and finally institutional commitments to long term monitoring networks are also discussed.

INTRODUCTION: A BENCHMARK IN MONITORING DESIGN

In 1973 Ted Munn, in a seminal paper, outlined the concepts and parameters for a globally dispersed network to monitor human impacts (Munn, 1973). Munn outlined operating principles, the need for a systems approach and lists of chemical and biological parameters that needed to be measured. In an attempt to review monitoring for ecological assessment, it is worthwhile to spend a little time on Munn's paper since in our opinion Munn's suggested design and assessment principles apply to making ecological assessments.

Munn felt early on that effective monitoring networks to assess ecological conditions on a global scale needed to follow certain principles. To us these principles are still valid today and are very applicable to our discussion on monitoring for ecological assessment.

First Munn stated that we needed to develop a conceptual model of the system and then use that model to help us design the monitoring and assessment program. Munn went so far as to suggest simple box models as possible means for carrying out these conceptual and mathematical models.

Munn expanded on the need for systems analysis of monitoring networks. He felt strongly that a global environmental monitoring network needed to be designed in such a way that the pathways of biogeochemical cycling could be analyzed and elucidated. This implied that monitoring networks need to be multimedia in concept and execution.

Second, he addressed the distribution of station or sampling sites. Munn proposed capitalizing on intensively studied sites in remote areas, intermediate areas and impact sites. While these were relative terms, his original idea was to start with intensive study locations; study sites which were implicitly set up to look at ecological processes. Munn recognized, however, that there were parameters that could not be

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adequately measured on intensive study sites. Examples were epidemiological data, data for estimates on species diversity, etc.

Third, Munn addressed problems of time issues as well as the scaling issues.

Fourth, Munn outlined operational principles including comparability of sampling techniques, need for intercalibration, establishment of long-term data banks, need for effective quality control measures and numerous other suggestions.

Fifth, Munn listed a number of specific parameters that needed to be measured on this network of sites. These are listed in his paper and only a brief overview is in order here. For example, pollutants such as SO_2, sulfates, CO_2, Nitrogen oxides, pesticides, toxic trace elements, etc. were all listed as pollutants of choice. Munn proposed that these all be measured in a variety of environmental media linked conceptually (and mathematically where possible) by models. Munn went on to describe the need for biological monitoring and outlined those meteorological parameters he thought necessary to look at in anticipation of global change.

Finally, Munn recommended that the system (to be called the Global Environmental Monitoring System - GEMS) should be built on existing networks.

Twenty years later (almost exactly) another group of scientists gathered at Fontainebleau, France to design an operational terrestrial observing system for the purpose of assessing change in terrestrial ecosystems (Heal, et al, 1993). This report outlined the fundamental requirements for a terrestrial observing system to assess ecological conditions on a large scale. It outlined site selection criteria, expounded on the need for the use of conceptual (and mathematical models) in the design of the system, reviewed data management issues and quality assurance needs. It also contained rather specific lists of parameters that needed to be monitored. It called for the use of existing monitoring networks as a starting point for the implementation of the system and came up with a name for this system (Global Terrestrial Observing System).

There is nothing, in my opinion, that is wrong with the Fontainebleau report except that most of the concepts in this report had been said twenty years before. It is discouraging, especially for an activity as important as assessment of ecological conditions, that we seem to have such difficulty implementing such networks. As a footnote, Munn's report was not even cited in the Fontainebleau report.

Have we made any progress in the ensuing twenty years since Ted Munn wrote his paper and published it as a SCOPE report? A great deal certainly has been written about various components that are necessary for assessing ecological condition. (In total fairness to Munn, his paper was catholic in it's coverage since he also included oceans and we are specifically limiting our remarks to assessing terrestrial ecosystems. The principles remain the same however.) For example, much has been written on the use of models and the importance of having a sound conceptual basis for helping to design environmental monitoring and assessment programs.

USE OF CONCEPTUAL MODELS

In fairness to the Fontainebleau report, they strongly emphasized the importance and value of models in the design and analysis of their proposed GTOS system. Others over the last twenty years have also written on subjects covered in the Munn paper. For example, Wiersma and others (Wiersma 1979; Wiersma et al. 1984 and Wiersma et al. 1991) expounded on the use and methods of application of models using simple linear differential equations in the design and execution of environmental monitoring programs most of which were aimed at assessing ecological change in natural ecosystems. A report by the National Academy of Sciences endorsed the value of conceptual models in the design of environmental monitoring systems in the more general case (NAS 1990).

From the above, it should be apparent that understanding and trying to incorporate conceptual and mathematical models of ecosystem functions and processes is extremely helpful to understanding the ultimate well being of the ecosystem. The Fontainebleau planners, thinking on a larger scale, also recommended the use of vegetation distribution models to help deal with the difficult issues of scale and wide spread geographical coverage.

Are there examples where the use of a well planned conceptual model (and then a mathematical version of the model) has been successfully employed in a large scale ecological monitoring pro-

gram during the last twenty years? Certainly the US EPA's Environmental Monitoring and Assessment Program has been more developed along independent media lines rather than around a unifying concept of how an ecosystem might be functioning. For example, there is a water group and one for forest and one for coastal estuaries, etc.

But there are, in my opinion, good examples of the effective use of conceptual models in an ecological assessment program. For example, the Direct/ Delayed response project of the National Atmospheric Deposition program seems in my opinion to meet this requirement. A recent review of this program by the National Academy of Sciences indicated that the design of these site intensive studies depended heavily on the use and implementation of conceptual models that helped define the processes operating in the studied ecosystems (NAS 1995). These models in turn helped to direct the study and focus the sampling efforts and even helped determine the methodologies employed.

Another example of where models were used in the design of a long-term ecological assessment program is in the Nordic countries and Canada. For example, Bernes et al. (1986) proposed that a network of intensive study sites be established where a variety of inter media samples would be collected with the intent of determining the integrated anthropogenic impact on these sites. Explicit in this design, of course, is the use and development of conceptual models. In Canada a series of such intensive sites have been established (Anon. 1989). As a footnote here, the Nordic program has been implemented into a multi national effort. From my knowledge of the network it is a good example of how to do such a network (designed to assess ecological conditions) correctly. Of course in the United States one cannot talk about integrated site intensive studies on ecological assessment that are based on sound conceptual models without mentioning the long term Ecological Research Network (Franklin et al. 1990). It does appear that we are making some progress in the use of intensive study locations to help us carry out ecological assessments.

ECOLOGICAL MONITORING NETWORKS

Does the above emphasis on site intensive studies mean there is no place for extended sampling networks as exemplified by the EMAP? The answer is of course no! Munn again addressed this issue in 1973. He recognized that for any parameters the assessment of spatial variability and the extension of the information derived from the site intensive studies needed an extended sampling program. But the key issue here is that the extended stochastic sampling efforts were derived from the research and monitoring conducted on intensively studied sites. This then allows the parameters that are measured on the stochastic sampling scheme to be readily set back into the conceptual paradigm which of course immeasurably improves our ability to understand the stochastically extended data sets. The danger of not doing it this way is of course that we end up collecting data for the sake of collecting data.

A good example of how this can work well is the national Surface Water Survey of the US National Atmospheric Deposition program. In this case the designers, based largely on their scientific knowledge of the biogeochemistry of lake systems which was derived in turn largely from site intensive watershed studies, were able to choose acid neutralizing capacity as the key parameter. The program is generally considered to have successfully answered the question of what is the condition of lakes in the United States (see NAS 1995). One needs to add that the program was also successful because the questions framed for its development were specific and well focused and there was continuity and consistency of management support for the program.

ECOLOGICAL MONITORING PARAMETERS

Once the decision has been made to develop a widely distributed stochastic monitoring program, the question becomes one of what to measure? We assume that the appropriate conceptual base has been developed, however. Usually the attempts to supply these answers takes the form of lists of parameters to be measured. These in turn fall into two categories—parameters necessary to characterize a specific site and indicators that hopefully will give a clue to the condition of an ecosystem.

These lists are many. For example a number of documents have discussed what parameters need to be measured on sites (site characterization). The World Meteorological Organization (1980) published a list of abiotic parameters that needed to be measured. This same document also gave suggested measurements for biological parameters. Wiersma et

al. (1988) discussed measurements that should be measured on integrated monitoring sites and Bruns et al. (1990) expanded on these concepts. Detailed sampling methods, as well as parameters to measure, are given for the Nordic countries program (see Bernes above) (EDC Programme Centre 1989) and suggested measures for integrated monitoring program (site intensive) are given by Rovinsky and Wiersma (1987).

The Fontainebleu report also provided exhaustive lists of parameters, some designed to assess site specific studies and others more geared to extended sampling efforts. But in our opinion even these latter were based on solid functional theory of how terrestrial ecosystems operate.

One trend that we would want to avoid would be any tendency toward merely enumerating species as if presence or absence of any species was a good indicator of the health of that ecosystem. In my opinion, again, we need to rely more on the fundamental processes of the ecosystem such as nutrient cycling and energy flow rather than some enumerated parameter. Perhaps what we should be doing is attempting to link species distribution more closely with functional properties of ecosystems.

EPA in an attempt to develop a set of parameters for monitoring in their EMAP program, held a major symposium dedicated solely to ecosystem indicators. The symposium contained many good papers and ideas which added to the already extensive body of literature in this area (see for example papers by Regier 1992, Rapport 1992 and Messer 1992 to mention a few). Many exciting and new concepts were put forth at this symposium which gives us great hope for continuous improvement in the future in our ability to carry out assessments of ecosystems.

For example, one of the more exciting ideas was the paper by Kay and Schneider (1992). In this paper the authors attempt to develop a fundamental set of concepts (almost a set of first principles) based around the Second Law of Thermodynamics which could help guide our thinking about how an ecosystem organizes itself and in turn carries out its functions. Their attempt is exciting not only for the uniqueness of their concept (although in fairness others have proposed a similar concept, see Prigogine et al. 1972) but in their bold attempt to begin to link ecosystem function to the fundamental physical principles which in reality guides all life. In truth as such concepts develop and are empirically studied, they could ultimately present the final conceptual basis for very effective ecological assessment programs.

SCALE

Temporal and spatial scales represent significant factors in the design and implementation of an ecological monitoring network. Scale is crucial in the conceptual modeling of the ecosystem, in field methods of data acquisition, and in data integration and analysis (e.g., NAS 1995). One central problem regarding scale is that variables and processes may (or may not) change at different scales (Wessman 1992). Spatially, for example, stomates are the primary control mechanism for transpiration at the level of the leaf while climate regulates this crucial ecosystem process at the broader scale of vegetation (Jarvis and McNaughton 1986). On a temporal basis, variable time lag responses by plant species have been detected in a five-year nutrient addition study on old field plots at an LTER (Tilman 1988).

Historically, most ecological models function at a single scale (Ustin et al. 1991) or theory does not explicitly address scale (Wiens 1909). Nevertheless, there are notable efforts to address scale in ecological models that would be useful for design of monitoring networks. For example, hierarchy theory (O'Neill 1988) holds promise as a conceptual approach to scalar integration across disciplines for global change studies, especially in identifying variables at a scale needed to interface atmospheric and ecological processes and in detecting the level of scale where predictive power is maximized. The Global Terrestrial Observing System (Heal et al. 1993) recommends using a nested set of patch, landscape, and regional models to provide insight to data requirements and testing of global models; GTOS also delineates core field measurements across five model types based on scale, including stand, landscape and biome. Another example of scale-related modeling is the global vegetation-biome by Prentice et al. (1992) based on plant physiology and dominance, soil properties, and climate.

One inherent problem in ecological modeling and monitoring design is that there is no single "correct" scale for study of ecological systems. This view is supported both by theory (e.g., O'Neill 1988, Wiens 1989, Levin 1992) and the practical limits of

meeting monitoring objectives (National Research Council 1990). Levin (1992) has indicated that "each (biological) species observes the environment in its own unique suite of scales of space and time." For example, Davis (1989) has indicated that the long-term response of vegetation to climate change (based on the paleoecological record) has been individualistic, i.e., species by species rather than a community-wide uniform response.

The issue of scale is also crucial to data acquisition within a global monitoring network. Fortunately, several technological developments appear to hold considerable promise. Research tools like remote sensing (Roughgarden et al. 1991), the global positioning system, and geographic information systems (Wessman 1992) have facilitated research efforts to address issues of scale among disciplines for global change studies. A successful example of this approach is the First International Satellite Land Surface Climatology Project (ISLSCP) Field Experiment (FIFE). The FIFE experiment was designed to test soil-plant-atmospheric models developed for small-scale applications at the level of the leaf and canopy (1 cm to 10 m) and to develop methods to apply the models at larger scales that are relevant to general circulation models (Sellers et al. 1992). FIFE focused on biology as a control on interactions between the atmosphere and the vegetated land surface; FIFE investigated the use of satellite data to quantify small-scale biophysical data for model input (Sellers and Hall 1992).

One logistical problem of scale is that labor intensive field-based measurements preclude extensive efforts at replication and sampling on larger spatial scales with a resultant scalar disparity between groundtruthing field data and remotely sensed imagery. Thus, small-scale, point observations may be difficult to interface with synoptic data based on satellite sensors. However, some progress has been made on this problem by ecologists like Running and Coughlan (1988) who have developed regional applications of forest ecosystem models that use important driving variables (like leaf area index, a ground based point value) that can be estimated using satellite remote sensors (Running and Coughlan 1988). Also, as noted above, the FIFE study has made significant contributions to understanding and dealing with this aspect of the scalar issue.

Since various feedbacks, nonlinearities, and discontinuities may effect patterns and processes across scales, it is crucial for accurate data integration that monitoring networks be multiscalar in design (Levin 1992, Wessman 1992). Both GTOS (Heal et al. 1993) and a recent subcommittee report of the National Academy of Sciences (NRC 1995) address criteria and issues of scale in monitoring design and data integration. The latter report recommends careful thought in the planning stages of interdisciplinary studies, especially in regard to inherent spatial and temporal scales and the processes they represent. Additional research on scale is clearly needed but the lessons of projects like FIFE provide a useful approach on which to base future work to improve understanding of this crucial factor in the design of monitoring networks.

INSTITUTIONAL COMMITMENT

Finally, one cannot talk about ecological assessment without considering some of the institutional aspects (i.e. management). Ecological processes take place over a relatively long time frame (not in geological terms perhaps but certainly in human time scales). Therefore any ecological assessment efforts need to have a long term time frame associated with them. In our opinion there are no exceptions to this rule. The search for a quick indicator that will give us effective ecological assessments over relatively short time frames is a futile search. We believe that we can develop sometime in the future a set of parameters that can give us relatively quick estimates of how an ecosystem is doing but these will absolutely need to be set within two fundamental givens:

1. They will need to be solidly grounded in fundamental theory related to process and functioning of the ecosystem itself.
2. They will need to have a long term data set against which they can be interpreted.

Unfortunately, particularly in the US, it has been difficult to develop these long term data sets. This is primarily due to the vagaries of US Government spending patterns (see Wiersma 1994). As indicated above, we have some serious questions on how the US EPA has designed and implemented their Environmental Monitoring and Assessment Program yet we also have been a consistent supporters of the

program primarily because we saw it as the most significant commitment to date from the US Government to carry out on a large scale and over a long term time frame a major ecological assessment program. We had hoped that the original design would eventually incorporate a set of long term site intensive studies and the stochastically sampled indicators would be integrated into the function and process studies underway in the site intensive studies. We still hold this hope and believe that events are slowly perhaps, but surely moving the program in this direction.

The greatest threat however to the EMAP program is not it's scientific design but the willingness of management to keep a significant funding base in place to allow us to begin to develop the data bases needed to make intelligent ecological assessments.

Other disciplines (in the US) have been able to accomplish this. For example, the Agricultural Experiment Stations in the United States have carried out continuous long term studies for over 100 years on important issues such as long term productivity of soil—data that is essential to understanding our ability to assess human capacity to maintain a continuous food supply on a changing land base. Similar examples are found in the US Fish and Wildlife Service's duck wing surveys for pesticide residues (Wiersma 1994). We have been less successful in the environmental area although other countries have been more successful in this area (see the example given above for the Nordic countries).

Related to this is the need for archiving of samples over long periods of time and the management of data bases that will maintain their usefulness for long time periods. Of particular importance in the data area is the way we manage and archive the metadata needed to understand how our studies were carried out.

CONCLUSION

In summary what are the ingredients of a good ecological assessment program? There are certainly no secrets here. Munn outlined the essential features 20 years ago. In summary, we will put our own interpretation on Munn's thoughts:

1. We need to link our ecological assessment programs to a conceptual basis. While ecological theory is still developing, there is a body of useful theories based largely on ecosystem function and processes that are linked to energy utilization including nutrient cycling, carbon flow and hydrologic cycles that today provide us with a good basis on which to build our ecological assessment capabilities. This implies that today we need to rely heavily on site intensive studies where process and function are more easily studied.
2. Space and time scale questions still need to be addressed, but parameters that are measured stochastically need to be closely linked with function and process studies. Theories are being developed to address these issues also.
3. More fundamental ecological theories need to be looked at, tested and integrated into our assessment methodologies.
4. Stochastically dispersed sampling efforts are valuable in their own right however; particularly now and in the immediate future when they are aimed at characterizing and then tracking certain fundamental parameters which help us describe and characterize existing ecosystems. The assumption here of course is that we know something about ecosystems and therefore can postulate measures to assess them, but perhaps equally important we need to establish for certain fundamental parameters (i.e. species, presence, growth rates, standing biomass, spatial distributions) a long term database against which we will be able to formulate future hypotheses and help to interpret results of other indicators.
5. Institutional infra-structure will make or break even our best laid and designed programs. Commitments of resources over the long term are essential in any effective ecological assessment program.

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SUBJECT III: CONCEPTUAL FRAMEWORKS AND SCIENTIFIC AND MANAGEMENT FOUNDATIONS

Papers and discussions during this joint presentation and Panel session focused on the nature of the conceptual bases, and scientific and managerial principles of monitoring for ecological assessment. Participants detailed experiences with conceptual approaches and experiences relevant to compliance-based, probability-based survey, and intensive site-based monitoring activity, among others. For each conceptual framework or approach explored, participants addressed the relation between socioeconomic systems (for example, values, program structure and management, and Agency mission and philosophy) and ecological system properties (that is, species, biodiversity, landscape patterns, and ecological processes). Issue areas included: assessment question source and design and their relation to system complexity and integrity; the nature, availability and validity of conceptual ecosystem models and condition indicators which need to be developed to integrate system complexity (that is, ecological and socioeconomic) into monitoring for ecological assessment activity; the scientific, technological, infrastructural, intellectual, financial, and organizational resources needed for planning and implementing monitoring for ecological assessment; and, the need for, and feasibility of a common North American approach.

Developing and Applying a National Ecosystem Concept in Canada

Ed B. Wiken[1]

Abstract.—In Canada and elsewhere, the ecosystem concept has taken on a much more practical and fundamental meaning in the past decade. The reasons are not academic but more so it results from the common realization that resources must be managed more prudently, that environmentally sensitive decision-making must be encouraged and that resources of individual organizations must be handled more effectively. The management of and decisions affecting the nations ecosystems can no longer be conducted in an isolated and sectoral context. Public interests, resource stewardship, environment/health linkages, environment/economy relationships and sustainability goals are among many factors which are calling for the application of a broader ecological perspective.

To think, plan and act in terms of ecosystems is seemingly a logical route but it is equally extremely tasking. The qualification and experience of professionals, the mandates and jurisdictions of organizations, the disparate sources of information, the expertise in reductionism and specialized sciences, and the traditional forums for decision making are among many barriers. More fundamentally, the scientific knowledge about ecosystems is weak— basic characteristics of individual ecosystems are seldom understood, key ecological relationships of systems are poorly known and the capacity to track the changes taking place in ecosystems is limited.

Cornerstones in developing an ecosystem concept are:

- accepting and applying an broadly based ecosystem definition;
- developing an understanding of ecosystems;
- establishing a common ecosystem framework;
- structuring an ecological monitoring capacity; and
- building a capacity to conduct ecological assessments.

INTRODUCTION

Why should people from Toronto care about the high latitudes of the Arctic? Why should the aboriginal people in the Northwest Territories care about the activities in the Russian heartland or the Mexican coffee belt? Why is the habitat of the Great Central Plains important to North Americans? Why should urban dwellers be concerned about the biodiversity and sustainability of distant forests? Perspectives regarding ecosystems within Canada and across the North American continent are changing. Like people around the world, North Americans are increasingly aware that the continent's vast distances seem suddenly to have shrunk (Wiken and Lawton, 1995).

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The long range transport of airborne pollutants from Russia and dust from North Africa to the Canadian arctic, the spread of radio active particles from Chernobyl to Labrador or the introduction of zebra mussels to the Great Lakes system remind us of what the consequences of human actions, no matter how distant. Failing to understand the intimate connections and their impacts is increasingly leading to significant social, economic and environmental consequences.

As events around us make clear every day, we face serious ecological challenges and must fundamentally change how we make decisions regarding goals like sustainability—*meeting the needs of the present generation without comprising the ability of the future generations to meet their needs (WCED, 1987).* While this phrase is used freely in many places, it has particular importance to ecological monitoring and reporting functions. Significant ecosystem changes happen over periods that are equivalent to human life-times. This is a marked contrast to the way we normally expect to judge the consequences of change. Instead of just viewing situations in terms of years or days, it has sanctioned the long term. This added orientation to sustainabilty places greater importance on measuring and evaluating phenomena over the long term and is thus more compatible with ecological processes (i.e., cold temperate forest ecosystems mature over 60-80 year periods, ecosystems cycles may take decades to be understood).

Making decisions that have an ecosystem focus are difficult and tasking. It is largely because our understanding and knowledge of ecosystems are weak. Important contributions to improving the basis for decision-making will come from efforts that provide objective and accurate ecological information. Ecological monitoring and reporting represent initiatives that are addressing these gaps. Enhancing our ability to apply ecosytem approaches to issues and concerns needs to be holistic, incorporating environmental and socio-economic factors.

ECOSYSTEM CONCEPTS IN NATIONAL REPORTING

The third comprehensive national report for Canada is scheduled for release in 1996. A major part of the report will be devoted to the analysis of Canada's twenty large ecosystems (i.e., ecozones) and two other parts that will concentrate on the more traditional perspectives (i.e., forestry, agriculture, urban) and priority issues (i.e., climate change). Work is also continuing on the development of national environmental indicators. Much of this work is based on the legislated mandate that was received with the passage of the Canadian Environmental Protection Act in 1988. It commits the Government of Canada to provide state of the environment information to Canadians on a regular basis. The national report is produced on a five year basis, and indicator bulletins and other products are produced over a shorter term.

The underlying purpose of this work is relatively simple: increase the understanding of trends, their causes, consequences and significance; provide the context for improved decision making at all levels, from individuals to government mangers; and measure progress toward sustainability. The scope of the work covers the entirety of Canada's large ecosystems, various resource sectors like forestry and agriculture, major issue like biodiversity and climate change, urban areas and lifestyles and basic concepts and strategies.

Ecological Concept

There are many ways to approach an ecosystem concept. Many models were reviewed and they included process based models, spatial models, lifecycle models, energy exchange and through flow models, plant and animal biased models and so on. These are useful for specific scientific purposes and as basic background references for discussion. However, the majority were too detailed for addressing general public audiences that national reporting targets. Elements had to be extracted from these models and blended with other ideas.

Ecosystems

Ecosystems are perhaps easier to comprehend at the global level. The earth or the ecosphere in the largest ecosystem. For the general public, it is commonly seen as a mixture of people and nature (Figure 1). In more technical terms, people are viewed through the social and economic systems of which they are a part; these are, however, sub-sets of ecosystems. Nature essentially means the environment or the biological and physical parts of the ecosphere.

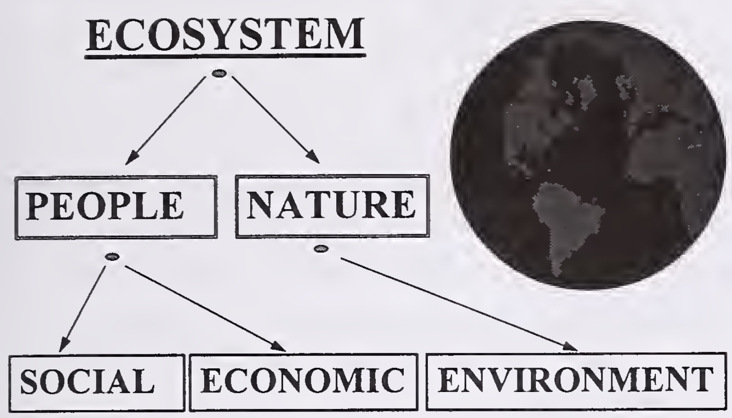

Figure 1. The concept and parts of an ecosystem.

Thus, ecosystems consist of plants, animals , humans and other organisms, together with air, water, soils, and rocks. The mosaic of characteristics and the geographical locations that occur with individual ecosystems is fairly discrete. Large ecosystems like the 'arctic', the 'Great Lakes', 'the Sonoran Desert' or the 'prairies' would be examples. With either of these examples, they have very particular types of biophysical characteristics , specific geographical locations and support definite kinds of human activities.

Ecosystems can be described in different ways, as natural, modified, cultivated, degraded or built. Native prairie grasslands are natural ecosystems, a forest which has been selectively logged is a modified ecosystem, a wheat-field or an orchard is a cultivated one. A degraded ecosystem is one such as a heavily polluted wetland whose natural productivity has been reduced to an insignificant level. A town or city is a built ecosystem.

Whether ecosystems are heavily modified by human activities or remain in a wild state, they can be thought of as hierarchical; they operate and can be defined at different levels. We may visualize a number of smaller ecosystems as nested within larger ones at higher levels. At the highest level is the global ecosystem -- the ecosphere. The ecosphere consists of lesser ecosystems, large and small. Large oceanic and terrestrial systems each contain several levels of smaller systems. The components of ecosystems and ecosystems themselves interact over time.

Ecosystem Concept for Reporting

National reporting is an inclusive process and must respect the interests and perspectives of many different groups. For purposes of simplicity, the adopted ecological concept has three core elements:

1. The use of goals based on ecological sustainability/world conservation strategies.
   -a FOCUS for examining issues ecologically.
2. The application of an ecological framework of information.
   -a CONTEXT basis for understanding ecological conditions and trends.
3. The focus on questions concerning ecological interactions.
   - a means to illustrate ecological RELATIONSHIPS.

The first part is intended to encourage an ecosytem approach to the analysis of and basis for the issue(s). The second part is designed to organize the pertinent information that exists on particular ecosystems. Thirdly, the questions are posed to promote a greater degree of analysis from the standpoint of interdependencies and connections.

Ecological Sustainabilty and Conservation Strategies

Professionals, lay people, industry and governments have been among many to make progress on deciding on goals and measurements for sustainability. To be ecologically sustainable, activities should meet fundamental and equally significant goals:

- an economic objective: the production of goods and services:
- the social goal: the maintenance and enhancement of the quality of life; and
- the environmental goal: the conservation and prudent management of the environment

In keeping with the intent of the World Conservation Strategy (IUCN, UNEP, WWF, 1988) and Agenda 21 (UNCED, 1992), the requirements of ecological sustainability are seen as:

- maintenance of life-support systems;
- preservation of biological diversity;
- maintenance of the productive capacity of species and ecosystems;

- efficient use of nonrenewable resources; and
- breaking the cycle of poverty and ecological degradation.

Ecosystem Framework

Defining ecological sustainabilty is difficult enough. If we do not fully know what ecosystems we have, what their properties are or how they function and interact, how can we determine ecological sustainabilty? Only by understanding ecosystems holistically can the full consequences of human activities be understood and behavior and attitudes modified. Traditionally, we have taken a reductionism approach to looking at ecosystems. Government departments, universities are largely compartmentalized into disciplines and departments that specialize in understanding parts/components of ecosystems. This has been effective in developing skills and expertise in a variety of fields of study but at the same time we failed to spend as much effort in understanding what we took apart. Throughout the world, land, water, fish, trees and animals were thought to be environmental resources that could be managed and used in isolation of one another. But it is increasingly apparent that, one way or another, almost everything is connected —people and the environment, different parts of the environment, economy and the environment.

An ecosystem information framework must be holistic and comprehensive to provide meaningful information for today's assessment needs. As well, it must recognize basic characteristics of ecosystems including:

- they have boundaries not borders. While lines are often used on maps, these spatial limits are porous edges through which various processes operate and materials flow;
- they exist as a hierarchy systems nested within systems, from local to global;
- they are dynamic with change being normal and sometimes unpredictable;
- they are characterized by simple to complex interactions occurring within and among all levels and systems;
- they have limited assimilative and carrying capacities; and
- they include people and our activities which have significant impacts on sustainability.

4 Questions

The third element of our conceptual approach is based on the use of four questions (Figure 2) that attempt to look at cause-to-effect relationships and connections.

- What is happening? (condition, baseline, trends)
- Why is it significant? (links between human activities and environmental changes; environment-economy implications; environment health implications)
- What is being done about it? (current policies, action plans, guidelines, knowledge)
- What are the future implications? (likely outcome of current strategies and activities; gaps)

THINK, PLAN AND ACT IN TERMS OF ECOSYSTEMS

We plan, act and manage in terms of spaces. Our own property, municipalities, regions, provinces state sand countries. Having a spatial element in an ecosystem approach was essential for reporting purposes. Working on the basis of jurisdictions (i.e., provinces, states,), however, was not particularly helpful as a start-

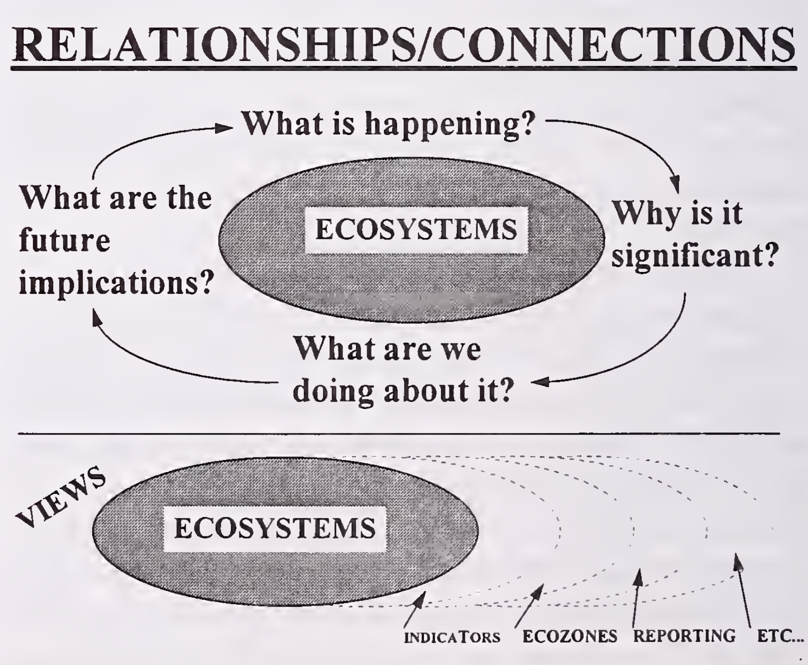

Figure 2. Questions on ecosystem relationships and connections.

ing point. If an ecosystem approach was applied, it had to be based on ecosystems. When the focus starts, instead, from the jurisdictional standpoint, it tends to turn discussions into matters of jurisdictional blame and responsibility before ecosystem issues can get explored. Once the more substantive issues on ecosystems are discussed, then jurisdictional matters can be tabled.

Terrestrial And Marine Ecosystems

Canada is a large country (e.g. 9,970,000 square kms). Over 45 percent of the terrestrial ecosystems are forested, 24 percent are arctic, and lesser amounts are associated with agro-ecosystems, large wetlands and freshwater areas. The marine ecosystems cover large portions of the Arctic Ocean as well as parts of the Pacific and Atlantic oceans. These ecosystems themselves and their environmental components have been highly valued resources by Canadians of all walks of life. Since Canada's early beginning, they have collectively been a key to Canada's economic and social well-being.

Understanding and solving today's problems requires a greater degree of ecological knowledge than ever. Industries, governments and individuals need a more comprehensive approach to better predict the effects of ongoing activities to guide what actions should be taken in the future. Answering these types of questions requires having the integration of information from many sources and the advice of many specialists.

Inadequacy of Existing Information

Canada is very immense. It is sparsely populated in most places and consists of many different ecosystems. The size and diversity are primary factors in making information collection a daunting task. Of what information exists, it is typically spread among many specialized agencies. The aim of most monitoring systems still is to measure selective media within the environment (i.e., water alone, air alone,) and to serve single use purposes (Figure 3) ; this is directly the opposite of some of the newer ecological monitoring requirements where various media need to be sampled to serve multiple purposes. Our strengths in specialization (i.e., wildlife, waters, atmosphere, oceans,) from international to local levels is, in part, a mirror image of some of our overall weaknesses. Surprisingly when much of it is drawn together, information is typically incomplete.

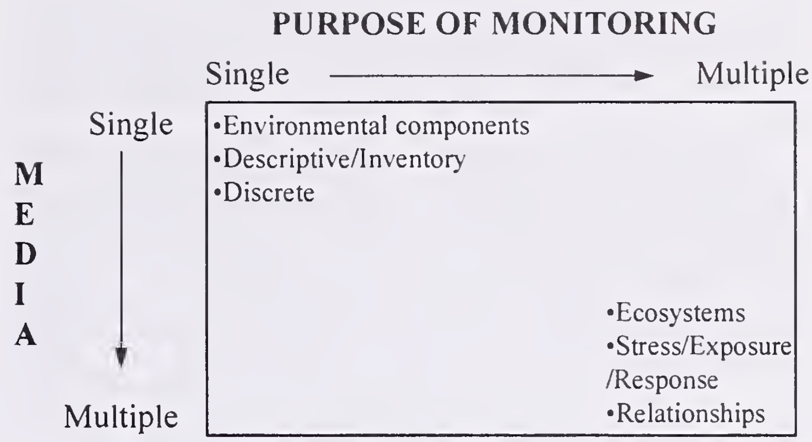

Figure 3. Relationships between the purposes of different monitoring systems and the media being monitored.

Building An Understanding

For over a decade, a series of cooperative partnerships and research agreements with governments, universities and private agencies were initiated to develop a national ecological framework for Canada. The basic catalyst for these initiatives was a commitment to new policy thrusts to mange resources prudently and to encourage sensitive environmental decision making, largely through the adoption if an ecosystem approach. To move in this direction a nation-wide ecological framework was required to provide standardized, multi-scale geographical reporting and monitoring units. The framework was essential to anchor and enhance the capability of both government and non-government organizations to assess, monitor and report, regionally, nationally and internationally on environmental quality and sustainability of ecosystems in Canada. The broader context is increasingly vital to evaluate diverse political, environmental and economic views.

The spatial framework is based on a common system of classifying and mapping ecosystems—terrestrial and marine (Wiken, 1986; ESG, 1995). The information base describes ecologically distinct areas of the earth's surface at different levels of generalizations, ranging from the broad scale of ecozones to the more detailed ecosection levels. Many jurisdictions and organizations now apply this system across Canada to characterize ecosystems. There are 15 major terrestrial ecozones and 5 marine ecozones. The terrestrial ecozones, for example, are subdivided into 217 ecoregions, 1030 ecodistricts and so on to cater other levels of management which may be more regionally

based. The spatial framework serves as a common ground for interpreting existing and new information about ecosystems independently of jurisdictional borders.

Cooperative studies undertaken with EPA (Corvallis Lab) have led to a common ecosystem framework between Canada and the USA at the ecozone level.. The development of this ecosystem mapping and characterization work was recently expanded to include Mexico through the assistance of the Commission on Environmental Cooperation (CEC).

Integration of Information

A major goal behind this framework was to link relevant and existing biophysical (environmental) and socio-economic sources of information. We did not have the financial resources nor time to create the ideal type of information. Most agencies in Canada are faced with substantial resources constraints but fortunately *poverty makes for partnerships*. The integration work was not approached as an overlay process but as an integration process. National data sets that had a potential for fleshing-out the ecosystem framework with additional data were collected using different mapping assumptions, sampling/reporting units. time series, etc. A fair degree of testing and indeed professional judgments were required to merge the data and to build links.

The ecological map units have acted as a comprehensive set of information folders. The folders allow different agencies and jurisdictions from across Canada to contribute their expertise and information on particular elements of ecosystems. The framework is not owned by anyone and serves as a simple protocol to build a profile and understanding of Canadian ecosystems and their sustainability. Some of the data which is linked includes:

- the CanSIS National Soil Database;
- the National Socio-economics Statistics
- the National Protected Area Database;
- the Soil Carbon Database;
- the Canadian Forest Inventory Database;
- the Threatened and Endangered Species Database;
- the Agricultural Census;
- the AVHRR Land Cover Database;
- the Migratory and Breeding Bird Surveys; and
- the Surficial Geology and Permafrost Database.

The ecosystem framework may be thought of as just a tool to organize information and to structure some idea of what ecosystems are based on exiting data. It is much broader than that and is the most immediate catalyst to think, plan and act in terms of ecosystems. The ecosystem spatial framework and notion are powerful concepts for planning and managing human activities. But they are not enough. Both must be complemented by new approaches to monitoring and research. Together they can provide a realistic basis for renewed attitudes and practices to safeguard ecosystems and the people the future of the earth.

ECOLOGICAL MONITORING IN CANADA

Ecological monitoring and environmental monitoring are not synonyms . The scope and intent behind them are quite different. To day, the fundamental questions which are not being answered by monitoring networks involve concerns about ecosystem carrying capacity (Rees and Wackernagel, 1994), ecosystem health, ecosystem integrity, multiple use, and ecosystem functions and processes.

Existing Monitoring Networks

While current monitoring systems may do well in meeting their original goals, they are lacking for purposes of implementing an ecological approach. The synopsis of Canadian monitoring networks perhaps is not unlike the situation across North America (Figure 4). Throughout Canada, there are not many sampling sites that have a long term record of greater than ten years. This has major significance when many ecological processes can only be understood over decades and when sustainability strategies are couched in the context of multiple generations. Sampling sites are biased to where most people live ,which in Canada is along the 49 parallel. However, ecosystem issues are not restricted to where the majority of people live but are nation-wide. Most of the existing sampling sites measure the physical parts of the environment like water. Comparatively less is done to measure other important facets like biology and land use. Monitoring networks as a whole are not well integrated nor are there coordination mechanisms to promote linkages between major networks. In certain sectors in Canada

CANADIAN MONITORING NETWORKS

SYNOPSIS OF EXISTING NETWORKS	SIGNIFICANCE
•FEW LONG TERM RECORDS	•LONG TERM VIEW NEEDED
•SELECTED AREAS SAMPLED	•COUNTRY-WIDE INTERESTS
•LARGELY PHYSICAL MEASURES	•ECOSYSTEM MEASURES NEEDED
•LIMITED INTEGRATION	•ENVIR. & SOCIO-ECONOMIC
•ISOLATED SOURCES	•COMMON REQUIREMENTS
•EXPANDING DEMANDS	•SHRINKING RESOURCE BASE
•LIMITED AGENCY EXPERTISE	•CROSS SECTOR INTERESTS

Figure 4. A synopsis of the current Canadian monitoring networks and their significance to current needs.

like forestry, a concerted effort has been made to meld different federal/provincial/territorial efforts. However, there is no parallel effort in the broader context to coordinate activities across a range of national and regional networks dealing with forests, atmosphere, soils, water, wildlife, human activities, etc. Co-location of sampling sites is not common but ecosystem issues cannot be analyzed without a context for perspectives like condition, exposure and response. Knowing what the deposition of a particular pollutant is of little meaning if we cannot determine, for instance, the responses and effects that take place in the soils, vegetation and people. Of what information exists, there are problems with data quality and comparability.

A number of reviews of existing monitoring programs have concluded that different strategies be adopted to make extended use out of existing networks or be used as a basis for developing new networks. The strategies include: modernize, integrate, reorientate, build alliances, and adapt and improve (Wiken, 1994). The first four essentially involve strategies on how to do things better and the last one is a case of doing things right. The Acid Rain Early Warning System and Ecological Monitoring and Assessment Network both represent improvements for purpose of providing a footing for ecological information.

Roles and Responsibilities

In Canada, there is no one single agency of government which is responsible for ecological monitoring and very few country-wide mechanisms to foster the needed changes. The Ecological Monitoring and Assessment Network (EMAN) initiative of Environment Canada is perhaps the strongest overall coordination mechanism to surface since the federal/provincial Research and Monitoring Coordination Committee of the 1980's. New initiatives undertaken by the Canadian Forest Inventory Committee (CFIC) and through the ARNEWS and Model Forest Program are other examples of moving towards a more holistic view to monitoring and assessment.

The federal government, provincial/territorial governments, private industry, public environmental groups share roles in monitoring activities. At the federal level, there is no singular department with overall monitoring responsibilities. The federal Department of the Environment (DOE) mainly monitors air, water and waterfowl resources, the Department of Fisheries and Oceans monitors fish and marine waters, Forestry Canada monitors timber resources and forest species, the Department of Agriculture monitors soils and agricultural crops, and so on. At the provincial, there is a similar dispersion of monitoring activities across many different groups.

THE CHALLENGE

Monitoring does not exist in isolation of other activities. Although it is not ever consistent where the circle (Figure 5) ever begins, monitoring fits within an interwoven cycle, the sum of which is no stronger than its weakest part. Reporting in many ways is just the mirror image of monitoring; it is like the difference between data and information on the state of ecosystems. Having appropriate ecological data is crucial for producing objective and authoritative information. It is also crucial in providing a foundation for ecological analysis and actions.

Organizations need to be guided by an ecological vision and to build an ecological monitoring and assessment capacity to implement them. There have been innovative and early responses to this within different countries but a wider perspective is certainly needed at the North American level. There are many benefits:

- for responding to mandated responsibilities;
- for understanding the types and current conditions of ecosystems;
- to pursue external partnerships;

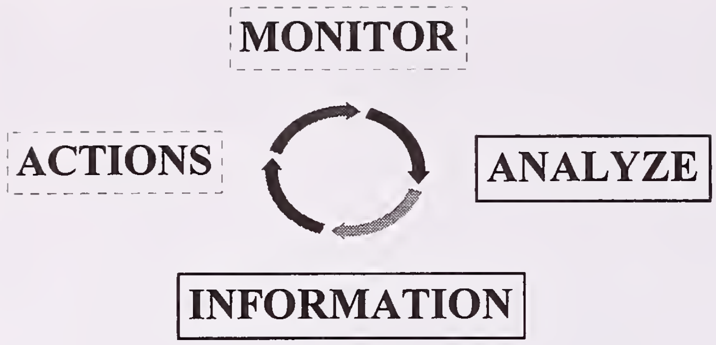

Figure 5. Reporting on the state of Canadian ecosystems.

- for development of standards and measurements;
- to improve coordination and cooperation;
- for developing indicators and reporting capabilities;
- for evaluating issues of a continental scale (and regional issues of continental significance);
- for discussing significant issues; and
- for developing analytical skills.

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SUBJECT IV: ECOSYSTEM RESOURCE GROUP PERSPECTIVES CURRENT PROBLEMS, NEEDS, AND OPPORTUNITIES

Each ecosystem resource group represented at the workshop asked to detail the history and current status of its monitoring and assessment activity. Presentations and panel discussions highlighted the differences and areas of commonality between and among ecosystem resource groups with respect to monitoring activity, funding and client support, commitment and satisfaction. Also, the session explored the interaction of applied, mission-oriented activity and the various basic science research communities. The session explored and reported on opportunities for cooperative approaches and scientific and technical collaboration. Four resource groups addressed this subject: (1) Forest and Rangelands, (2) Surface Waters and Wetlands, (3) Estuaries and Coastal Waters, and (4) Agroecosystems.

Canada's Model Forest Program - An Established Opportunity for Cooperative Scientific and Technical Collaboration in Ecosystem Monitoring and Assessment

John E. Hall[1]

Abstract.—Canada's Model Forest Program was established in 1992 to seek a working definition of the concept of sustainable development in Canada's forests. Most of the sites are into their third year of operation. The network of North American model forest sites provides a comprehensive research platform for advancing cooperative projects concerning ecological assessment of terrestrial and aquatic ecosystems of common interest within the three countries of North America. Key to the Model Forest program is that each site reflects local social, cultural, economic and environmental factors through a management mechanism that includes all key stakeholders.

THE CANADIAN PERSPECTIVE

Canadians share with North Americans the common objective of sustainable development. We, in North America, are well situated to take a global leadership role in the development of effective approaches to the study, monitoring and evaluation of ecosystems. Our continent spans from the Arctic to the tropics, offering a microcosm of the range of ecosystems that are found around the globe. The complexity that socio-economic systems add to the ecological systems is also well represented in how each nation approaches the organization and management of its forests differently. For example, in Canada, the forests are owned in large tracts by the provincial governments. The forests that are primarily managed for timber are under few other pressures. In the United States of America (U.S.A.), the forest ownership is characterized more by a combination of either federal or state governments or private enterprise and is subject to greater recreation and other non timber demands expressed by its population. The Mexican context is again different where much of the forest land is communal and population pressures are significant.

The Model Forest program consists of a network of sites that are located across North America that are managed through a partnership of diverse stakeholders. These sites are microcosms of the differences in ecosystems and in how those ecosystems are managed in North America. To illustrate opportunities for collaboration in ecological assessment, three case studies of the model forests in practice are presented in this paper. Two case studies focus on Canadian sites: the Foothills Model Forest and the Long Beach Model Forest. Both of these model forests include or share national park boundaries. The third case study describes the Calakmul Model Forest that is located

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adjacent to the Calakmul Biosphere Reserve in the Yucatan Penninsula of Mexico. The Model Forest program is well suited to dovetail with the North American effort to define and conduct effective ecosystem assessment within the context of working models of sustainable development. The model forest sites addressing the question of ecosystem description, analysis and monitoring would also benefit from this collaboration.

WHAT IS THE MODEL FOREST PROGRAM?

The Model Forest Program originated from the desire of the Canadian public and the Canadian Council of Forest Ministers to take a proactive approach in seeking a working definition of the concept of sustainable development in Canada's forests. The program is designed to assist forest managers to implement ecologically sound and scientifically advanced management practices and to demonstrate sustainable development in forestry and the management of forests for a broad range of values. This program represents an unprecedented forest initiative by Canada and the world to establish a network of model forests, complemented by an associated program of enhanced research and information exchange and dissemination.

The objectives of the Model Forest Program are:

1. To accelerate the implementation of sustainable development in the practice of forestry;
2. To apply new and innovative approaches, procedures, techniques, and concepts in the management of forests;
3. To test and demonstrate best sustainable forestry practices utilizing the most advanced technology and forestry practices available.

THE MODEL FOREST NETWORK

The initial network of ten large scale (areas greater than 100,000 hectares) working models of sustainable forests was established across Canada in 1992. Since that time, the network has expanded as other countries, including Russia, Mexico, the United States of America and Malaysia have become participants in the network. Interest in the model forest concept from other countries continues to grow. In North America there are presently ten sites within Canada, three sites in Mexico and three sites in the United States of America (Figure 1) representing a diversity of forest ecosystems and cultural and economic systems.

The Canadian network is supported by the Model Forest Secretariat located at Canadian Forest Service Headquarters. The function of the Secretariat is to encourage networking among the model forests by managing biannual meetings of the Model Forest Network Committee, made up of the model forest managers, arranging technical workshops, providing a network newsletter and an Internet server, and promoting cooperative projects and technology transfer among the model forests and the forestry community at large. The program is funded through contributions from the Canadian federal government and in-kind and financial contributions from the partners in the model forest organizations.

The International Model Forest Secretariat (IMFS) is located at the offices of the International Development Research Centre (IDRC) in Ottawa, Canada. Currently the Secretariat is involved in negotiations with Mexico, Russia, and Malaysia to establish further sites and more than twenty other countries have expressed interest in developing model forest sites in the near future. This level of international interest demonstrates the degree to which the model forest program has grown since Canada's initial invitation was made in June 1992 at the United Nations Conference on Environment and Development held at Rio de Janeiro for three countries to participate in the model forest network.

WHAT IS A MODEL FOREST?

Model Forests are created in a particularly innovative way that has proven to be flexible enough to facilitate diverse local solutions, and to have the ability to attract a wealth of research, expertise, and resources to bear on a comprehensive attempt at finding a working definition of sustainable forest management. Each model forest site is a result of a competition that provides a strong incentive for partnerships of diverse membership to form and seek common objectives and to then design a unique program that deals with the needs of the local community and the conservation of the environment within that community. Each model forest partnership includes representatives from the provincial and federal governments, industry, and environ-

Figure 1. North American Model Forests

mental groups. Representatives of private land owners, aboriginal peoples, universities, colleges and school boards, labour, municipal governments, recreation and sports clubs, and other non-government organizations also participate in many of these partnerships. Overall, more than 300 groups are participating in model forests across the network. Governments have given these groups the support and the opportunity to innovate, however, it is important to note that in most cases, the model forest participants went through a difficult phase in trying to establish consensus among diverse stakeholders.

For this type of decentralized and participatory management to succeed, it is necessary that all stakeholders be involved in a meaningful way. The participation of scientists and trained professionals is critical to guide the local organizations in choosing a course that meets short term needs with long term requirements of sustainable development. At the same time, it is necessary for local communities to commit themselves to understanding how their aspirations must be tempered with the ability of the environment to support their activities. The model forest organizations have brought together key stakeholders who bring to bear local knowledge with the scientific and professional expertise needed to solve common problems. This personal commitment of energy and enthusiasm to cooperative endeavors has proven to be much more powerful than when it is used to promote sets of objectives that are often exclusive or competitive. This process is constantly evolving as new opportunities arise.

HOW DOES A MODEL FOREST OPERATE?

Implementing the concept of sustainable development requires that during the development and implementation of management plans balanced consideration be given to all values of the resource. Some of the values considered are economic utilization of forest products, water quality, wildlife habitat, genetic resources, the conservation of undisturbed ecosystems, and recreational, cultural and social services provided by a given area.

To arrive at the best balance among the resource values for each site, the model forests depend on the broad array of perspectives and knowledge of their partnership members. Each model forest is administered by a board of directors that is made up of volunteers elected from the partnership. Where gaps in expertise or knowledge are identified, the board has organized technical committees that, on a voluntary basis, develop, review, and manage projects recommended to and approved by a board of directors. This process is viewed as a crucial learning experience as all parties become better aware of the diversity of forest values held by their partners. Each model forest partnership has formed a formal non-profit organization and have hired a small complement of staff to administer the model forest's operation on a day-to-day basis. The actual project work, such as the research needed to meet aspirations of partners, data management, networking and public awareness, and education is carried out by the partners or contractors.

CRITERIA FOR THE ESTABLISHMENT OF A MODEL FOREST

To qualify as a model forest the following criteria must be met:

1. The model forest must be approved by participating landowners.
2. The model forest must be managed by a partnership group of all stakeholders.
3. The model forest must manage all critical resource values and use the philosophy of integrated resource management.
4. The model forest must be of working scale and size.
5. The model forest must utilize ecologically sound forest practices and support research and development on the key issues related to sustainable forest management.
6. The model forest must support education and learning in the local communities.
7. The model forest should emphasize the transfer of technology and knowledge to other areas outside the model forest.
8. The model forest must be an active part of the model forest network and share experiences, successes, and failures with other model forest projects.

INTERNATIONAL VISION FOR THE MODEL FOREST PROGRAM

The Model Forest Program is well suited for collaboration as it leads to country-driven models of sustainable development that respect local political and socio-economic conditions, expands regional and

international cooperation and technology transfer, and draws on a wide pool of expertise and personal commitment from over 300 Canadian-based organizations participating in Canada's model forest sites. The Program also supports Canadian foreign policy interests by facilitating greater international dialogue on sustainable development of forests, particularly as it relates to trade and the environment.

THE CANADIAN PERSPECTIVE

It has always been clearly stated that "the Model Forest Secretariat will encourage other countries and agencies to join the network and, over time, it is envisaged that a self-sustaining network will operate as an international institution supported by the participating countries". In expanding the model forest network, Canadian experience together with that of the charter international partners, Mexico, Russia and Malaysia will be key in guiding future international developments.

OTHER COUNTRY PERSPECTIVES

The model forests are increasingly viewed as a major international initiative that provides grounding to the international policy debate about forests. The Model Forests are emerging as the most tangible example of a network of projects exploring the UNCED forest principles in action, fostering technical exchanges, and building an international common purpose of sustainable forest management.

Over 25 countries and a number of international institutions have expressed an interest in joining the Model Forest Program. While many of these countries could self-finance their own model forests, the developing countries seeking to join the Program would require financial assistance. Expansion of the Program would allow other countries and agencies to contribute to the costs of running the Secretariat and supporting model forests in important eco-regions of the world.

During the International Working Group on Forestry meeting held at Hull, Québec, Canada in October 1994, the countries and institutions present agreed to put forward the following option to the Commission on Sustainable Development in April 1995, seeking their support for "recognizing the value of a global network of model forest sites and encouraging nations to build upon this initiative".

ILLUSTRATING LINKAGE OPPORTUNITIES: CURRENT ACTIVITIES AT THE MODEL FOREST SITES

The focus of the North American Forestry Convention offer a useful introduction to the discussion of the model forest case studies and the opportunities for linkages between the North American Ecosystem Monitoring and the Model Forest Program.

The Focus of Activities of the North American Forestry Commission

The activities of the North American Forestry Commission can be grouped under the following categories.

1. To improve scientific understanding and awareness of the ecological structural of the North American biome.
2. To monitor and report on the state of North American forest ecosystems.
3. To foster the development of collaborative activities addressing continental sustainable forest management issues.
4. To explore the potential for improving links between forest science and forest policy for the sustainable development of continental forest resources.

The majority of the model forests are within their third year of operation. Within this time period many elements of strength as well as areas that will require further attention have evolved across the model forest network. The need for a clearer understanding of the temporal and spatial effects of the socio-economic system on the ecosystem has become more apparent. Three case studies will be used to illustrate some of these commonalties, such as the challenges of integrating protected areas with operational forest areas and of successfully interfacing with the local populations. The three sites selected for this paper were chosen to demonstrate the scope of characteristics among the sites and to illustrate examples where Canadian national parks are part of the model forest

land base and a site where a model forest shares a border with an established Biosphere Reserve. It must be noted that all of the model forest sites are equally suitable as case studies.

CASE STUDY 1 - THE FOOTHILLS MODEL FOREST

The Foothills Model Forest (2,218,000 hectares) is located in the province of Alberta. Its land base includes Jasper National Park (a UNESCO World Heritage Site). The Park's management is a charter partner with the model forest organization and through continued involvement with the model forest it has developed a close working relationship with the model forest partners recognizing the opportunities of working within the larger ecosystem represented by the model forest land base. The Park has assigned a full-time staff member to the model forest organization to work on trans-boundary issues.

Three areas of cooperation have been identified for immediate attention. The first is a conservation strategy for large carnivores that utilize the park and the operational land bases at different times of the year. This approach has also been endorsed by the Worldwide Fund for Nature. The second area of cooperation is in the development of a common method of ecological classification for all land tenures of the model forest and for the establishment and management of representative areas at all successional stages. In the third area of cooperation the park and the model forest will be working together to ensure that the needs for 'set aside' areas of certain ecosystems are met. The Park is best suited to manage zones of protection for certain seral stages while the operational forest areas will provide examples of successional stages.

The Park and the model forest partners are also working together to develop a common approach to socio-economic issues. For example, there is a direct conflict between commercial river raft operators and habitat needs of nesting ducks. Both activities need the same stretch of water at the same time of the year. It is important that this type of conflict move beyond the initial stage of pure emotion versus pure financial motivation. In this case, neither side has knowledge of enough information to make an informed decision. The model forest and the Park partners are keen to provide both sides of the issue with meaningful information. The Foothills Model Forest is twinned with the Chihuahua Model Forest in north-central Mexico and this arrangement has lead to continued exchange in education, forest management and project management expertise.

CASE STUDY 2 - THE LONG BEACH MODEL FOREST

The Long Beach Model Forest is located on the central west coast of Vancouver Island. It is characterized by the beauty of the ocean and of the temperate rain forest. The area is over 400,000 hectares and is home to a number of communities including five First Nations where traditional culture, spiritual values and a perspective of community stewardship of the forest provide input into the goal of sustainable development. The economic base is characterized by tourism, timber extraction and commercial fishing. There is also a National Park that is a partner in the model forest.

The Long Beach Model Forest is also characterized by an aggregate of often extremely divergent forest values. The board of directors is made up of fourteen sector representatives for interests such as youth, First Nations, commercial forestry and fishing industries, governments, education and recreation to highlight a few. The decision making of this group is based on consensus and requires unanimous agreement. This situation both strengthens and challenges the partnership. This process has demanded much time and energy from all participants but, has ensured that all participants are working together to incorporate their diffuse values into the decision making.

The Long Beach Model Forest in part aims to create a common understanding of the forest-ocean ecosystem and the impacts of natural disturbances, of climate change and of a variety of land uses on the watersheds and to understand the affects of ecosystem status on social and economic structures. The partners also are planning to develop a strategic plan for the long term ecological research for the area. They will embark on an education program that will encourage public inputs and increase awareness among the members of the communities, in particular the First Nations. Based on this understanding, the partners hope that the ecosystem can be better

managed to maintain its integrity and to support a more balanced array of benefits over the long term for all sectors.

CASE STUDY 3 - THE CALAKMUL MODEL FOREST

The third case study, the Calakmul Model Forest (380,000 hectares) is located on the Yucatan Peninsula in Mexico and shares a boundary with the Calakmul Biosphere (780,000 hectares), which is the largest biosphere reserve in Mexico. Many cross benefits are evident through the linkage that already exists between these two sites. Although this area has been populated for centuries, evidence of human intervention into the biosphere reserve for the extraction of mahogany and cedar logs and of chicle (a natural rubber product) is not obvious to the casual observer. Today the model forest supports a population of 16,000 people, most involved in subsistence farming.

The mutual benefit of the linkage of this model forest and the biosphere reserve is best described by the local leader Mr. Deocundo Acopoa, who is the director for both the model forest organization and the biosphere reserve. Mr. Acopoa has stated that "Through the linkage between the model forest and the biosphere reserve, international awareness of the resource management challenges and the economic realities of the local people who ultimately decide on how the area will be managed is increased". Also, the local effort gains greater credibility within the intentional donor community, a critical consideration for accessing funding for projects.

Locally, the linkage has had a number of positive results. The biosphere reserve has attracted ecotourists and researchers and a portion of their entrance fees to the biosphere reserve goes towards projects aimed at helping local people. New economic opportunities such as a cooperative hotel have helped towards the goal of diversification and are lessening the dependence on traditional non-sustainable means of utilizing local natural resources. There are also comparative studies underway on bird and large mammal populations inside and outside the biosphere reserve area. It has been the tradition in this area that the local people be very much involved in decision-making.

The public education and awareness program of the model forest depends greatly on existing local community organizations to deliver news of the research activities and other information so that local people are better prepared to participate and make more informed decisions. The Calakmul Model Forest is twinned with the Eastern Ontario Model Forest in Canada and this linkage is proving also to be a valuable conduit for information and increasing partnership development.

SUMMARY OF LINKAGE OPPORTUNITIES

Secretariat - initial one-stop access to the network

The Model Forest Network Management Committee is made up of model forest managers, and representatives of the provincial governments and the Canadian Forest Service. This committee holds network business meetings twice a year and also organizes special workshops on technical themes. The Model Forest Secretariat produces and administers an active communications program aimed at informing both the model forest partners and an ever widening audience about the model forest program and developments within the program through a network newsletter, an Internet server, and numerous speaking engagements and tours.

Strong Networking Processes

Networking between model forest sites has been formally established through the process of twinning. When a new model forest site is proposed, workshops are held with the partners of the proposed new site to inform them of the process of developing a model forest proposal. Representatives from established model forests participate in these workshops and once the new site is established it is twinned with an existing model forest as the first step in integrating the new site into the working network. Twinning has proven to be invaluable to both sites by raising public awareness of the projects and encouraging even stronger local participation.

Local Stakeholder involvement

The model forest organizations have always involved local stakeholders in planning and decision making. These processes are open and this transparency has encouraged the expansion of participation

in many ways including critical comment and new, supportive initiatives. In this manner grass roots initiatives can be addressed in the model forest context.

Operational and Conservation Links

All model forests are improving levels of knowledge of the impact of various management scenarios within both protection and conservation areas. Operational land bases provide information on the ecological succession of value to managers concerned with maintaining ecosystem diversity and neighboring reserve or conservation areas provide benchmark data to determine the levels of impact of interventions. Networks among researchers can be improved with increased availability of information about activities and challenges faced at the interface between protection areas and conservation areas.

CONCLUSION

There are many opportunities for linkage with the Model Forest Network that would mutually benefit scientists and research institutions that seek to better define more effective approaches to the study, monitoring and evaluation of the ecosystems in North America. An observation made at the latest workshop held in the state of Michoacan in Mexico to develop a formal Model Forest Proposal can be used to illustrate the benefits of linkage. The proposed model forest area in Michoacan will encompass an existing biosphere reserve established for the protection of the wintering habitat of the Monarch Butterfly - an insect that migrates between southern Canada and a few specific stands of trees in the state of Michoacan across the United States of America. At the workshop it was noted that increased global awareness of the butterfly and its wintering habitat needs had been effectively achieved through the Man and the Biosphere Program and now through the linkage with the Model Forest Program an increase in global awareness of the needs of the people that must live with and protect the butterfly will be achieved to the benefit of all. It now remains that challenge to ensure that ecosystems are understood well enough to ensure that managers can be better advised to allow for best management decisions.

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Forest Health Monitoring Program in the United States

K.W. Stolte[1] and H.G. Lund[2]

Abstract.—The United States Department of Agriculture's Forest Service and the U.S. Environmental Protection Agency (EPA) are conducting a multiagency Forest Health Monitoring (FHM) program. This program has 4 main components: Detection Monitoring, Evaluation Monitoring, Intensive Site Ecosystem Monitoring, and Research on Monitoring Techniques. The focus of the program is to evaluate forest ecosystems for condition, changes, and trends in indicators of the health of U.S. forest ecosystems, with known statistical confidence in the estimates. The FHM program also wants to monitor indicators of pollutant exposures and habitat condition, and seek associations between human-induced stresses and the ecological condition of the forests. Finally, the FHM program wants to be able to provide annual reports and periodic interpretive assessments on the ecological status and trends to resource managers and the public.

The evaluation of the condition of forest ecosystems is performed in Detection Monitoring through ecological indicators of forest condition that address ecosystem inputs, components, processes, and outputs. These indicators primarily focus on the vegetation, pathogens, pollutants, soil, and other key components and processes of the forest ecosystem. A probability-based sample in Detection Monitoring allows determination of forest condition through cumulative distribution function analysis, spatial analysis, and assessment of overall health using data from plots, remote sensing, and other survey and monitoring techniques.

A similar program has been developed by EPA for rangelands in the U.S., called the Environmental Monitoring and Assessment Program (EMAP) Rangelands program. Sampling plots will be located on grid points that best address range ecosystems, and will be statistically linked to the same base grid as the FHM forest plots. Assessment endpoints and indicators are specific to rangeland ecosystems. The Rangeland program is in the later stages of testing prior to implementation.

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El Programa de Proteccion de Salud Forestal

RESUMEN.--El Servicio Forestal del Departamento de Agricultura y La Agencia de Protección Ambiental de Los Estados Unidos (EEUU) están llevando a cabo un programa de seguimiento conjunto de salud forestal (el programa FHM). Los cuatro principales componentes de este programa son: detección, evaluación, estudio intensivo insitu, e investigación de las technicas de control. El objectivo del programa es evaluar el estadio, cambios, y tendencias en los indicadores de salud, de los ecosistemas forestales en Los Estados Unidos por medio de estimados estadisticos de fiabilidad reconocida. El programa FHM también pretende estudiar los parametros que indican la exposición a elementos contamientes y la condición del habitat, a la vez que investiga asociaciones entre daños provocados por el nombre y la condición ecologica de los bosques. Finalmente, el programa de FHM aspira a proporcionar informes anuales y evaluaciones periódicas en relación al estado ecológico, y expectativas a los administradores de recursos y a la opinión pública.

La evalucción del estado de salud de los bosques se lleva a cabo durante la fase de detección mediante el siguimiento le los indicadores ecológicos de la condición forestal que reflejan las nuevas contribuciones, componentes, procesos, y productos del ecosistema. Estos indicadores se centran principalmente en el suelo, vegetación, agentes patógenos, contaminantes y algunos procesos clave en el ecosistema forestal. En base a un estudio de probabilidad sobre una muestra en la fase de detección es posible determinar la respuesta de la población total mediante el analisis de la función del estado sanitario general utilizando datos obtenidos a partir de gráficos, inferencia remota y otras técnicas de control y seguimento.

La EPA ha desarrollado un programa similar en los EEUU para los terrenos áridos denominado "Environmental Monitoring Program y Assessment Program" (EMAP)-Programa de Evaluación y Control Ambiental: terrenos áridos. Los gráficos muestros se corresponden con los diagramas base utilizados en los gráficos forestales del programa FHM, aunque los indicadores y determinantes valorativos son especificos a los ecosistemas de tierras arridas. El Programa de Tierras Áridos se encuentra en las últimas fases de pruebas previas a su implementación.

The health of the world forest ecosystems has gained increased public and political attention with current concerns about acid rain, global change in atmosphere and climate, and a variety of insect, disease, and pollution problems. Monitoring of forests to describe their ecological condition and identify changes that may be occurring, is needed to provide the factual information base upon which public policy and private ownership decisions can be made. Providing this information in the United States is the goal of the U.S. Forest Health Monitoring program. Another national monitoring program, the Forest Inventory and Analysis program, focuses primarily on productivity and extent of U.S. forests (Stolte, 1994).

The Forest Health Monitoring (FHM) program is headed by the United States Department of Agriculture's Forest Service, and the United States Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP). Participants in FHM include the National Association of State Foresters, Bureau of Land Management, Tennessee Valley Authority, Natural Resources Conservation Service, Fish and Wildlife Service, and National Park Service.

Forest Health Monitoring is unique because it identifies early signs of systematic change, by determining the current status of indicators of forest resources and tracking any changes in their status over time. This is accomplished by plot and survey monitoring of indicators of ecosystem structure and function, so that any widespread, fundamental changes in forest ecosystems can be identified in the early stages of development. Off-plot data provided by other programs, such as information on regional pests, air quality and deposition, and climate, are used in an overall assessment of forest health.

Localized damage to forest ecosystems identified in Detection Monitoring is intensely monitored in Evaluation Monitoring, to determine the causal agent(s) responsible for the damage. Intensive Site Ecosystem Monitoring is designed to understand the fundamental mechanisms underlying the structure and function of forest ecosystems, so that indicators for Detection Monitoring can be identified and predictive modeling of forest ecosystems can project future forest condition based on current changes and trends. Research on Monitoring Techniques activity supports the other three primary monitoring components by improving the methods used in monitoring activities. This paper will primarily address Detection Monitoring, which at present is the most developed component of the program.

FOREST HEALTH MONITORING CLIENTS

FHM's primary clients are Federal, State, and private land owners and managers with responsibility for regional assessments of forest condition. In addition, other land owners and managers with smaller areas of forest can benefit from the land management policies based in part on FHM results, and from regional FHM data that provides a population-based estimate for forest ecosystems that can be compared to conditions within the smaller forest areas. In general, FHM benefits owners and managers of forest lands nationally and internationally by developing and validating key monitoring indicators, developing spatial analysis methods, developing risk assessment techniques, performing assessments of sustainability of forest ecosystems, and by transferring monitoring technology to interested cooperators.

CONCEPT AND DEVELOPMENT OF FHM INDICATORS

The FHM program has always been an assessment-driven program (Figure 1). Defined assessment endpoints are derived from a combination of needs and concerns of society, and a knowledge of forest ecosystem components and processes derived from research and monitoring performed at intensive study sites (e.g., Long Term Ecological Research sites). The functioning of forest ecosystems is categorized by components, processes, inputs, and outputs (Figure 2). The indicators in the FHM program that are used to monitor the status, changes, and trends in forest condition are directly tied to stated assessment endpoints, and link the endpoints to key components and processes of the forest ecosystem (Figure 3). These assessment endpoints determine what sampling (indicators) is performed in surveys and plots in the forest. The FHM assessment endpoints are diversity, productivity, sustainability, environment, aesthetics, and wildlife.

The endpoints are very parallel with the ecological sustainable management criteria outlined in the Santiago Declaration (Anonymous, 1995),

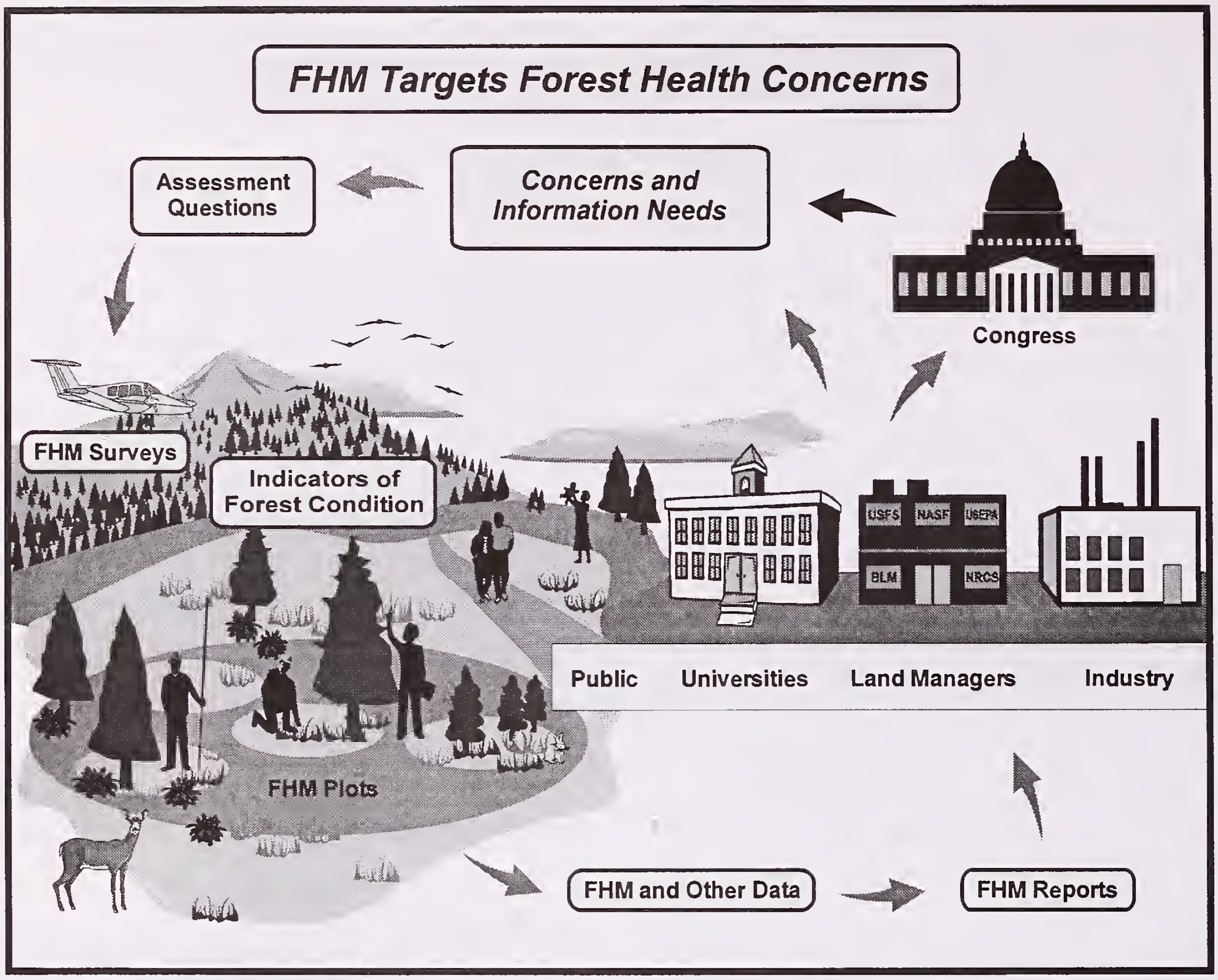

Figure 1. Concerns and Information Needs are identified by FHM from many sources including: the public, land managers, scientists, industry, government agencies, and Congress. These concerns and needs guide the FHM program in formulating relevant assessment questions about forest health. Assessment Questions are derived from concerns and information needs relating to biodiversity, productivity, forest environment, sustainability, wildlife, and aesthetics. Indicators of Forest Condition are characteristics of the environment that can be measured to provide quantitative data about forest ecosystems. Environmental indicators are selected, based on knowledge of how forest ecosystems function, to address FHM's assessment questions. FHM Plots are established in forest ecosystems for long-term monitoring of environmental indicators. Data from FHM plots are combined with other ground-based and aerial data to assess overall forest condition. FHM Reports synthesize diverse forest data to address specific assessment questions. Information in these reports helps policy makers and land managers make informed decisions.

namely productive capacity, biological diversity, ecosystem health and vitality, soil and water resources, and forest contribution to global carbon cycles. Since the FHM program's assessment endpoints are analogous to most of the Santiago Declaration criteria, many of the FHM indicators are the same or similar to those suggested in the Santiago Declaration.

In addition to these ecological criteria, the Santiago Declaration outlines socio-economic criteria and indicators, and legal-institutional-economic framework for implementation. The FHM program is working with the USDA Forest Service's Southern Forest Economics group, who has developed socio-economic and implementation criteria and indicators for forests, to integrate ecological and socio-economic criteria and indicators for a complete assessment of forest sustainability.

Indicators Of Forest Condition

In order to monitor the condition of U.S. forests, the FHM program had to identify ecosystem attributes that are common to many forest types. Indicators in the FHM program are currently being tested that can be linked to the attributes of a forest ecosystem. The FHM has identified 3 societal values (ecological integrity, consumptive values, and non-consumptive values) as the current goals of the program. These societal

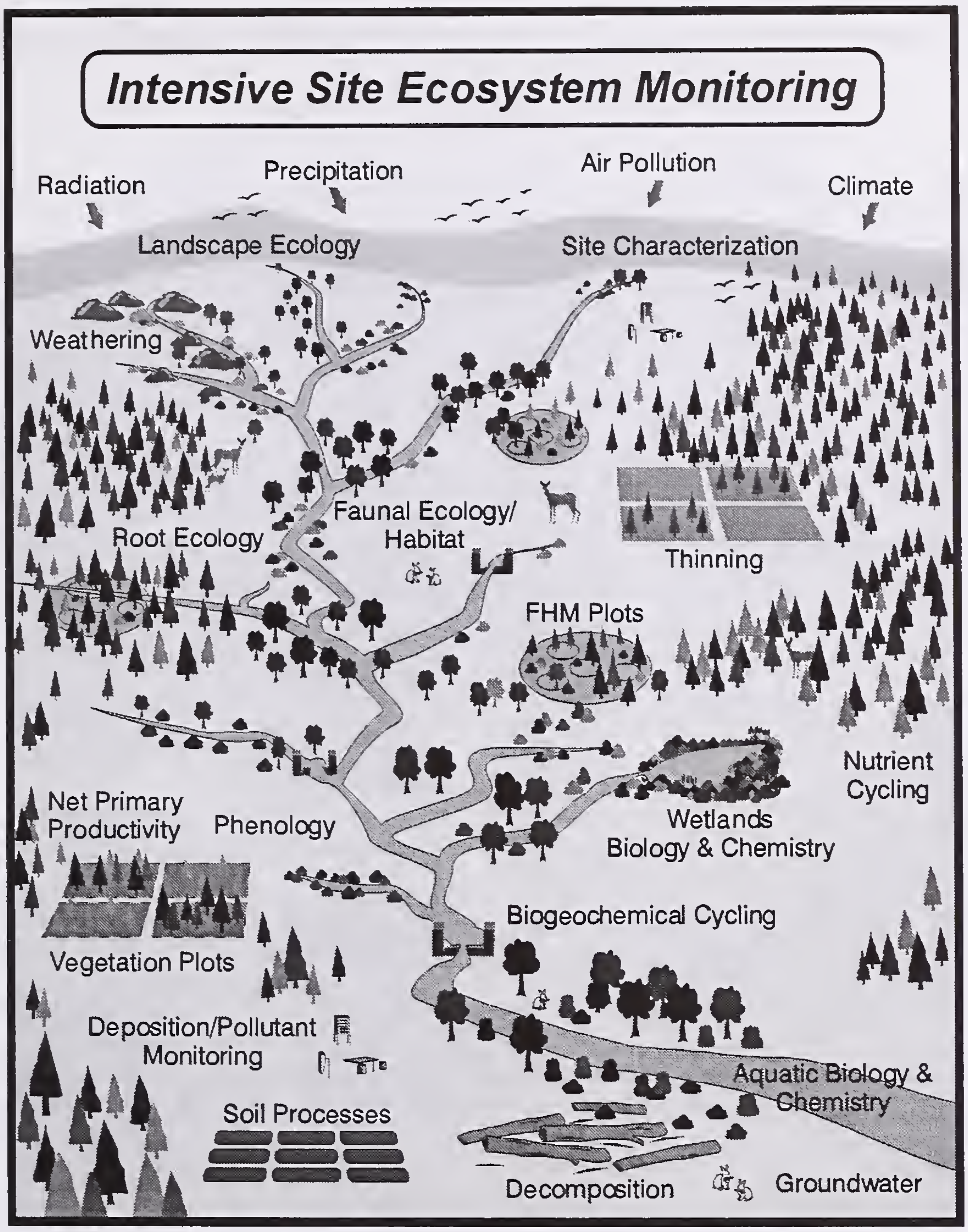

Figure 2. Intensive Site Ecosystem Monitoring (ISEM) is the intensive, continuous measurement and analysis of forest ecosystem components and processes at selected biologically representative sites such as Long Term Ecosystem Research (LTER) sites. The purpose is to provide detailed baseline information on key components of the selected ecosystems and for furthering our understanding of the processes and mechanisms responsible for significant changes in forest health. ISEM is designed to: correlate stressors with forest condition; improve monitoring in Detection Monitoring and Evaluation Monitoring; identify causal agents of change in forest condition; and improve estimation of future forest condition. ISEM will provide high quality, detailed information on key ecosystem components and processes that determine resiliency and sustainability of forest ecosystems. This will be accomplished through long-term monitoring at a limited number of sites representing important forest ecosystems. ISEM will provide a foundation for conducting and interpreting research at ISEM sites.

values are addressed by 6 primary assessment categories, termed endpoints (diversity, productivity, sustainability, aesthetics, forest environment, and wildlife). These societal values and assessment endpoints can be thought of as a screening mechanism to determine what attributes (indicators) of a forest ecosystem are important to monitor.

The FHM program has selected a number of indicators of forest condition that, either separately or in combination, can be linked to one or more of the assessment categories. These indicators are aggregates of 1 or more plot level measurements, typically averaged over the four subplots (Scott, 1991). The following indicators are currently in, or near implementation, in Detection Monitoring: growth, regeneration, mortality, stand structure and disturbance, vegetation diversity and abundance, condition of tree crowns, tree and sapling damage, leaf area index, lichen community diversity and pollution sensitivity, ozone bioindicators, and soil stability and fertility. Other indicators that have been undergoing site-specific and regional testing concerning the indicator criteria include dendrochronology and dendrochemistry, foliar chemistry, and root disease.

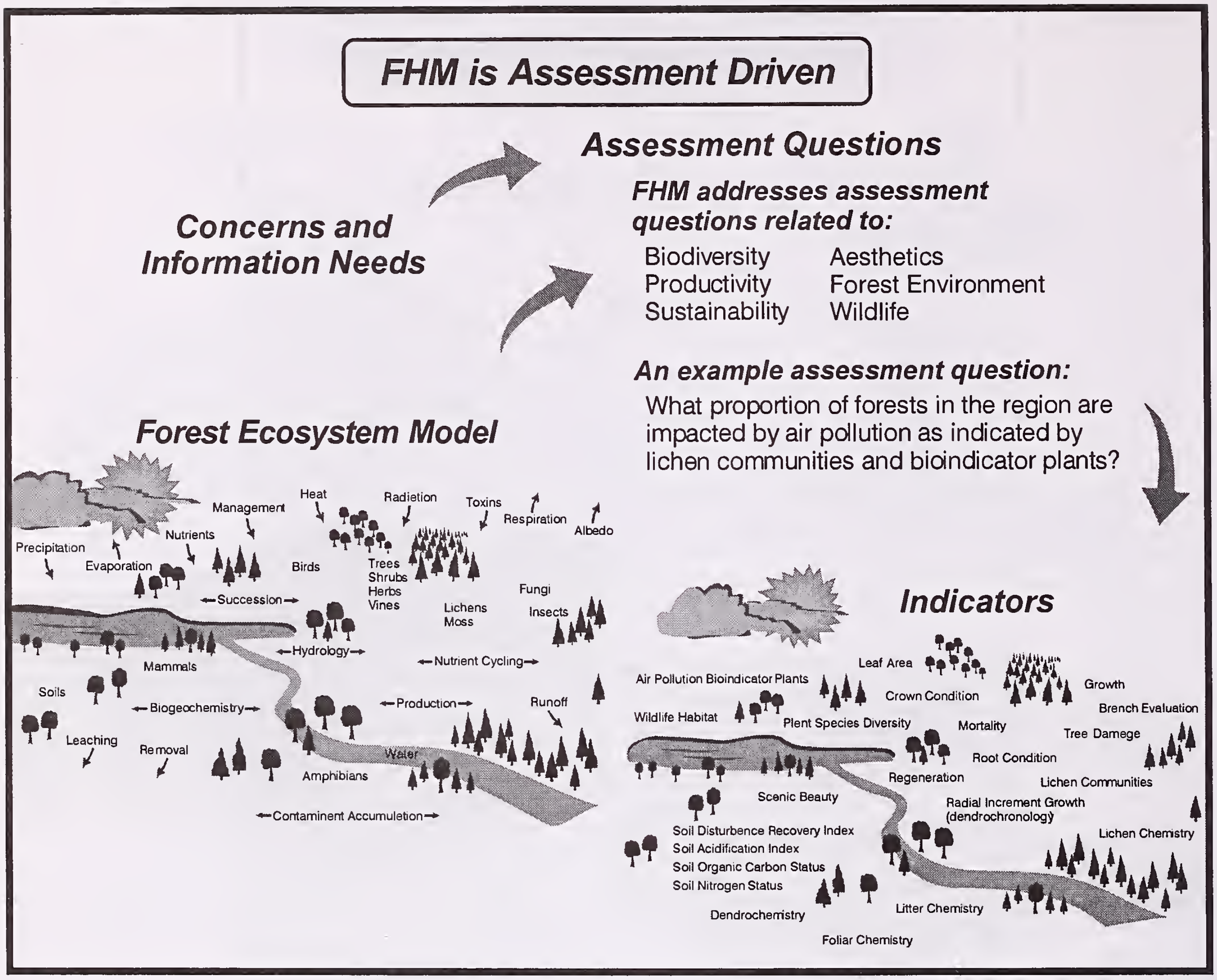

Figure 3. Assessment Questions are formulated based on: concerns about forest health and related information needs and knowledge of how forest ecosystems operate. Indicators are selected based on: their ability to provide information for answering assessment questions and knowledge of forest ecosystem structure and function.

A 2-4 person crew, depending on the number of indicators, performs the sampling in a single day (Riitters et al., 1991). Data are recorded on portable data recorders (PDRs) and sent electronically to the FHM Information Management Center, and samples are mailed to appropriate laboratories for species identification and/or elemental analyses.

Plot-level indicators are evaluated using population and spatial analysis techniques, and are linked through a geographical information system (GIS) with off-frame (off the 1 hectare plot) data collected in ground or aerial surveys by FHM and other associated agencies (Figure 4). This off-frame data includes regional evaluations of insect and diseases on trees, climate, and air pollution. These plot-level indicators and off-frame data are linked to key components and processes of a forest ecosystem that have been identified by intensive site research and monitoring, so that many facets of the forest ecosystem are being addressed.

Indicator Development Process

The FHM program recognizes that the validity of estimating condition and change in assessment endpoints of forests is dependent on the relevance and performance of the indicators sampled (Lewis and Conkling, 1994). The relevance of the indicator is determined through evaluation of the strength of the link between the indicator and the assessment endpoints. The performance of the indicator is evaluated on the basis of its stability through the sampling period, non-

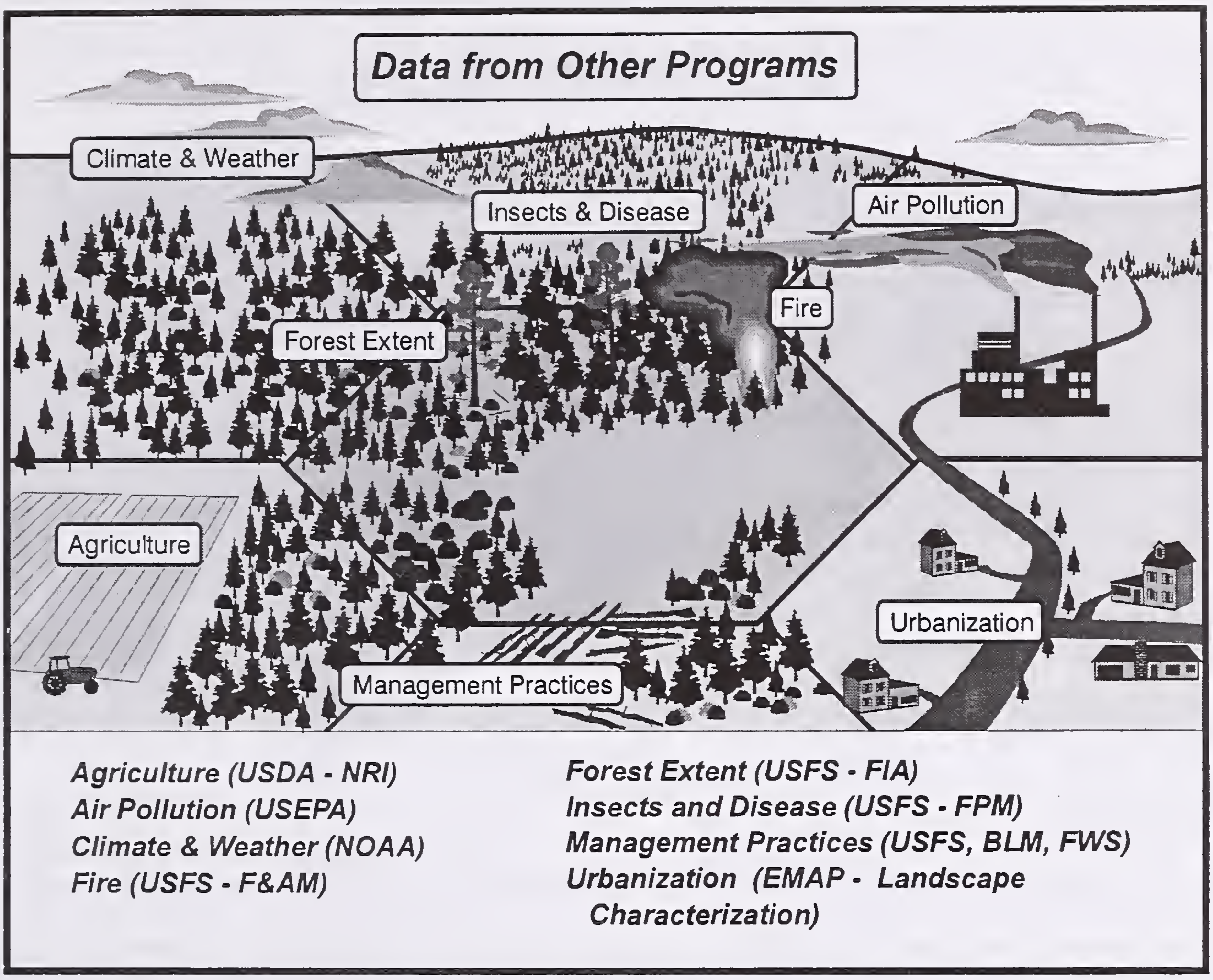

Figure 4. The FHM program will use information from other programs when assessing the overall condition and changes in forest health. This information is combined with data collected from FHM plots to evaluate current forest condition and to determine if forest health is static, improving, or degrading over time.

destructive mode of sampling, cost (time, expertise, equipment, and analysis), regional applicability, and strength of detecting changes in condition.

Sampling Approach

Forest ecosystems in the United States cover approximately 1/3 of the land area (about 300 million hectares). The U.S. forest ecosystems are diverse, ranging from subtropical forests in Florida to the boreal forests of Alaska. To monitor forest ecosystems over large areas and diverse climatic and topographic conditions, the FHM program has used the EMAP grid that consists of one large hexagon that covers the North American continent (Figure 5). Within this large hexagon are approximately 12,000 smaller (64000 ha) hexagons, which contain 4000 ha (40 km^2) offset sampling hexagons, located 27 kilometers apart. There are approximately 4,000 sampling hexagons that are estimated to contain forest ecosystems (Overton et al., 1990). This basic EMAP grid design can be intensified or de-intensified according to program goals, using multiples (intensify) or inverse multiples (de-intensify) of 3, 4, 7, 9, and 11. The design is focused on regional, not plot-level, assessments of indicators by using cumulative distribution frequencies analysis and other analytical techniques. The design allows for partial sampling, rotating panel with overlap, of a proportion of the plots, commonly 1/3, 1/4, or 1/7, with full spatial coverage to estimate population conditions with stated confidence.

FHM Is A Multiagency Program

The Forest Health Monitoring program is jointly funded and managed principally by the USDA Forest Service and the U.S. Environmental Protection Agency. Four other federal agencies, the National Association of State Foresters, 18 state forestry or agricultural agencies, and 13 universities participate in diverse operation activities including training, plot establishment, data collection, quality assurance and

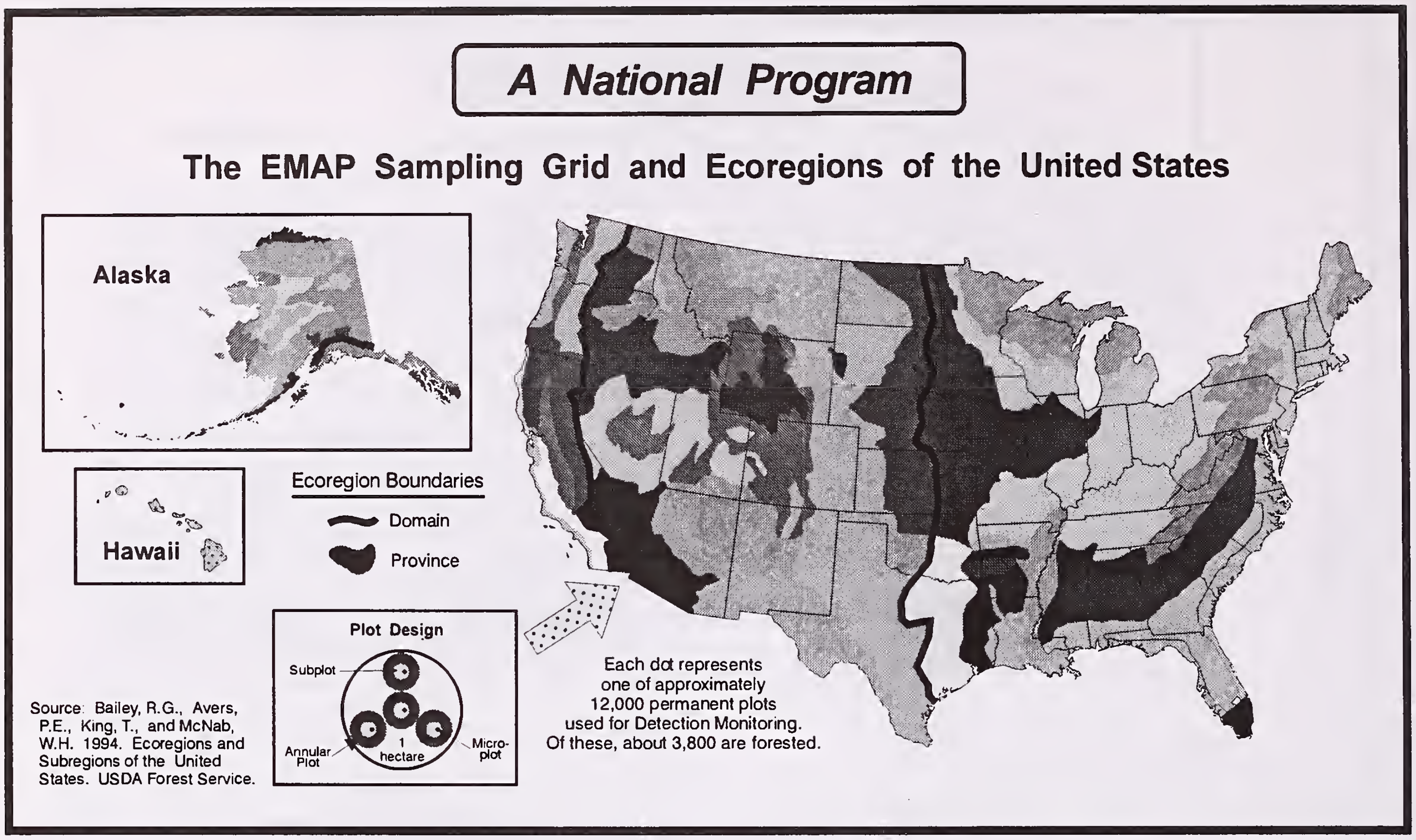

Figure 5. Forest Health Monitoring (FHM) is a long-term national program to monitor and report on the status, changes, and trends in the condition of the nation's forest ecosystems. Detection Monitoring—the largest and most developed component of FHM—provides regional population estimates of forest condition with known confidence. The other components are Evaluation Monitoring, Intensive Site Ecosystem Monitoring and Research on Monitoring Techniques. Detection Monitoring reports include data from:

- **Annual sampling of environmental indicators. These indicator data are collected by FHM field crews from a nation-wide network of permanent ground plots. The ground plots are approximately 1-hectare in size and are composed of 4 subplots approximately 1/60 hectare in size (inset). Ground plots are approximately 27 km apart.**
- **Aerial and ground-based survey data on forest insects, diseases, and other forest stressors collected by FHM participants.**
- **Data from other programs on factors such as climate, weather, air pollution, management practices, and forest growth.**

The sample design for establishing FHM ground plots, called the base grid, is formed from a triangular grid of sampling points. The base grid can be condensed or expanded to increase or decrease the density of the plots per unit area, as needed, to meet specific sampling objectives.

control, analysis, reporting, and assessment, and transfer of the technology to land owners and managers, both within the United States and internationally (Figure 6).

The FHM program also collaborates with other diverse agencies to obtain information on fire, climate and weather, insects and disease, air pollution, urban and agricultural encroachment, and forest extent and management practices to assess the overall condition and changes in forest health. This information is combined with data collected on FHM plots to evaluate current forest condition and determine if condition is static, improving, or degrading over time. Policy and land managers responsible for forests can then make informed decisions to protect or improve forest health.

Development of the FHM Program

The major problems that FHM has encountered, and any large scale, long-term monitoring program would have to address, are basically one of support for the program, and one of development of sound technical approaches to implementation of monitoring and assessment of data.

Program Support

Any monitoring program requires a long term commitment and guaranteed long term support. Monitoring programs are often implemented when there is an immediate need but support often falls off

Figure 6. Forest Health Monitoring is jointly managed and largely funded by the USDA Forest Service and the U.S. Environmental Protection Agency. Four other federal agencies, 18 state forestry or agricultural agencies, the National Association of State Foresters, and 16 universities participate in diverse activities including training, plot establishment, data collection and analysis, quality assurance and control, assessment, and reporting.

as new issues rise to the surface. A major problem then is how to maintain support for FHM and other forest programs. Here are some suggestions:

1. There has to be a need for the program to begin with, and that need must be felt at the levels where funding appropriations occur. Global climate change, sustainable forestry, biodiversity conservation, and desertification are major problems at the moment. Many nations have agreed to participate in the various conventions dealing with these subjects. Sound and efficient monitoring programs which address these concerns should be looked upon favorably.
2. The program must provide the information sought, be scientifically sound, and easy to comprehend.
3. The program must be able to survive changes in agency and government administrations.

Have the program required by law. Link to agreements made at UNCED and through the participation in various conventions.

Develop credible and persistent mentors at upper echelons. Even the most highly relevant programs need supporters in the upper echelons of government to continually bring to the forefront the major products the program is designed to address, results from recent studies, and the overall importance of the program. This support must occur where funding decisions are made.

Build partnerships at home and abroad. Flaunt these partnerships. The FHM program has implemented similar efforts abroad-including central Europe, Indonesia, and Honduras. Similar efforts can be initiated with private enterprise, USFS National Forest Systems, and other groups. Through research in the U.S. and abroad, we can test new theories, methodologies, and applications and improve the program for all countries concerned. Cooperation with other countries builds support for the program at home. If FHM is relevant to other countries where the technology has been transferred, then it will cause the U.S. to consider whether we should discontinue it if it is of such a value to other countries with similar forest ecosystems.

Get results out early, frequently, simply and through a variety of media. Administrators like to see results. The results should be easy to understand - making more use of graphics and less use of tables and equations. Results should appear in newspapers, reports, popular journals, as well as in scientific journals. FHM reporting consists of annual reports with limited interpretation, special case-study reports addressing the efficiency of various monitoring components, and comprehensive assessments every 3-5 years, with a comparison of multiple-year data and assessments of results.

Share credit and glory - but also share burdens. Your partners deserve equal recognition when results are made known. Let them take lead in getting results out. At the same time, when there are problems, involve them in the solutions.

Be honest. If forest ecosystem monitoring programs are not providing the needed information to forest land owners and managers, they

should be changed or discontinued. Programs should not be maintained if they are not providing the required information.

Keep trying to improve the efficiency of the program. As technology and analytical capabilities improve, so should the monitoring system. FHM is using a cooperative project in Indonesia to improve our monitoring systems at home by testing a variety of remote sensing techniques, and linking remote sensing techniques with ground-based plots and surveys. By pooling resources, equipment, and expertise, we can undertake studies that we could not afford to carry our on our own. Like many current federal programs in the U.S., the FHM program is facing cuts in funding. Reductions in budgets can be met by consideration of reductions in sampling intensity, reductions in frequency of measurements, or reduction in the amount of information collected in the sampling.

Technical Approach

To implement a national program of annual monitoring, data analysis, and reporting over large geographical areas requires the technical development on monitoring procedures that will give population estimates with known confidence. FHM has been developing relevant indicators, data quality assurance and control methods, information management systems, and spatial analysis and risk to sustainability assessment techniques in order to provide a sound scientific base for monitoring forest ecosystem health. Methods for transfer of this technology within the U.S. and to other countries have also been developed by the FHM program.

Status Of The FHM Program

The primary focus of the FHM program from 1990-1995 has been in the development of the Detection Monitoring component. Currently FHM has plots

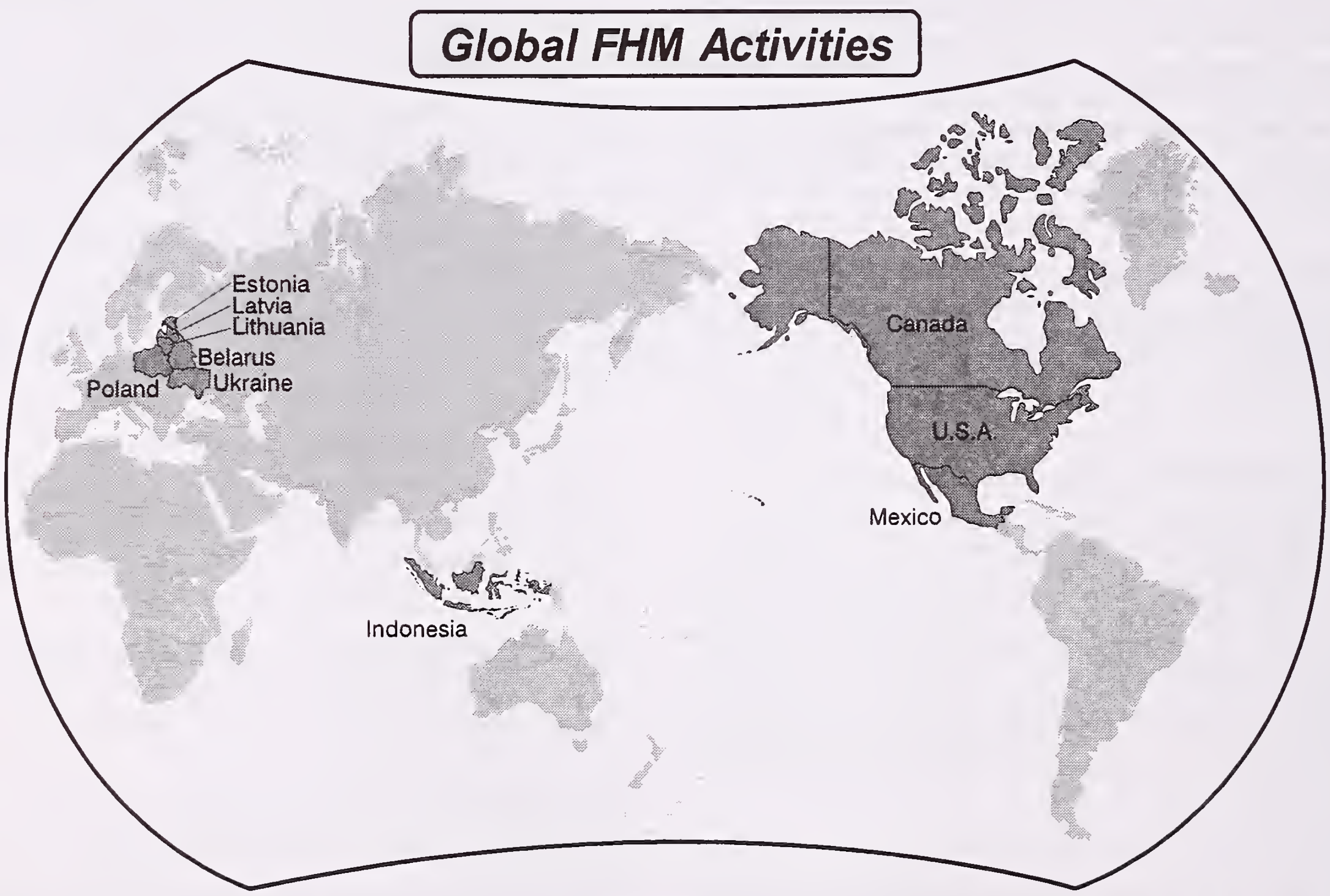

Figure 7. Internationally comparable data are needed to make global assessments of the condition, changes, and trends in forest ecosystems. These international assessments will eventually be accomplished through the use of compatible sampling grids and data collection. The benefits of international cooperation include: the development of a global forest monitoring system with high comparability among nations; extended research to develop and improve indicators and assessment techniques; and expanded review of FHM techniques. The mutual transfer of monitoring technology is accomplished through meetings, workshops, and training, and is currently focused on Detection Monitoring and on research to improve monitoring techniques. The goal is to develop forest monitoring programs in each country that are compatible with FHM. These programs will link to the U.S. program through collaboratively developed indicators, information management, and quality assurance and control programs. Currently most FHM activities outside the U.S. are funded by the U.S. State Department, U.S. EPA Environmental Monitoring and Assessment Program, and USDA International Forestry.

established in 18 of the 50 States, and 5 countries (Lithuania, Latvia, Estonia, Belarus, and Ukraine) (Figure 7), with initial trainings conducted in Indonesia and Poland, workshops to develop FHM monitoring plans for Honduros, and discussions and interest in the FAM program with Hungary, Czech Republic, Slovakia, Russia, Mexico, Canada and Brazil.

The Detection Monitoring component has identified societal values, assessment endpoints, and indicators to detect status, changes, and trends in forest ecosystem condition over time. FHM indicators have been tested in intensive-site and regional studies to meet statistical and logistical performance criteria. The comprehensive data quality assurance and con-

FHM Results

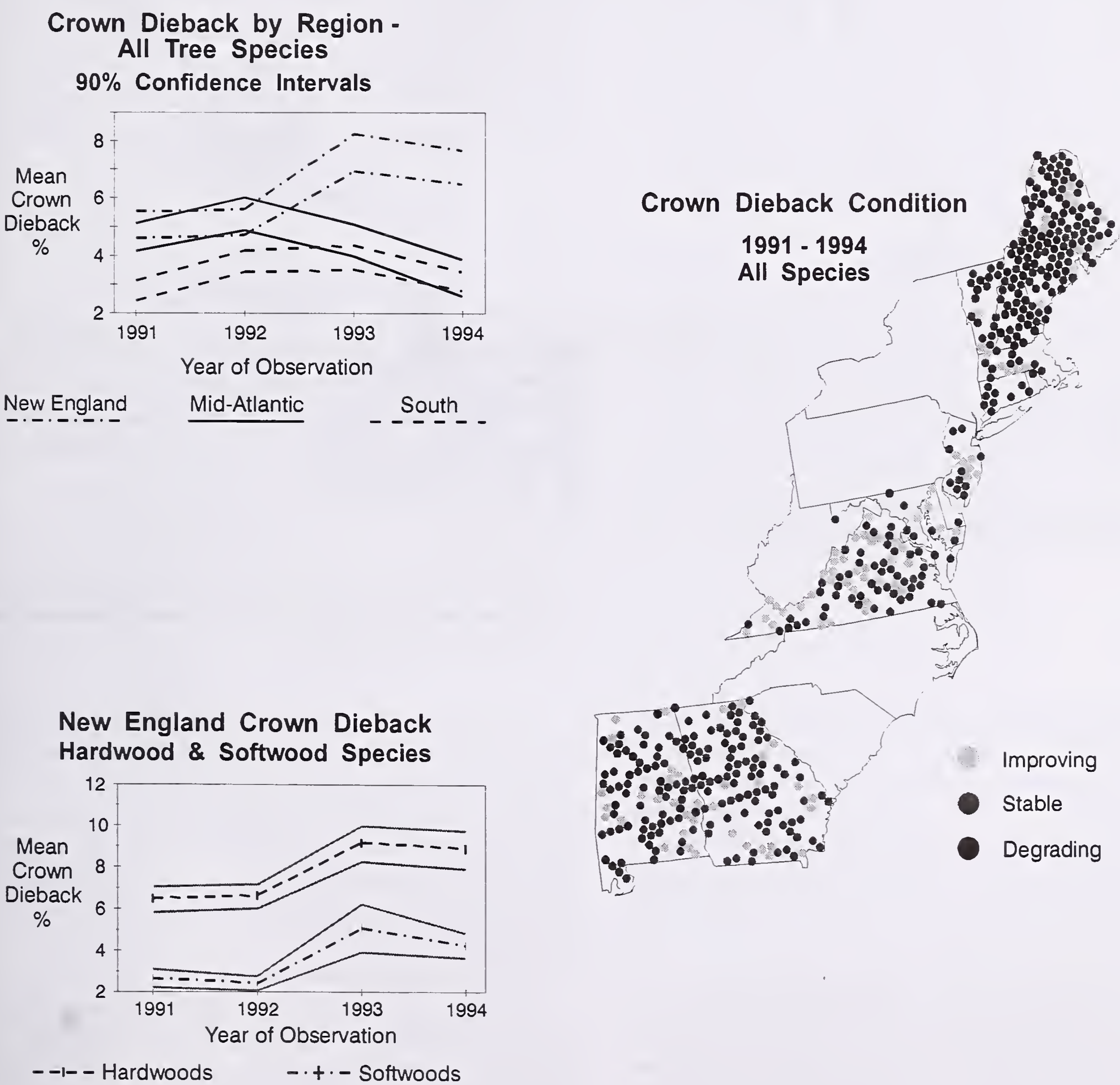

Figure 8. Crown dieback monitoring results for 1991-1994 in the eastern United States. Dieback has increased and is more severe in the New England area, particularly in western Maine. Hardwood trees are more severely impacted than softwood.

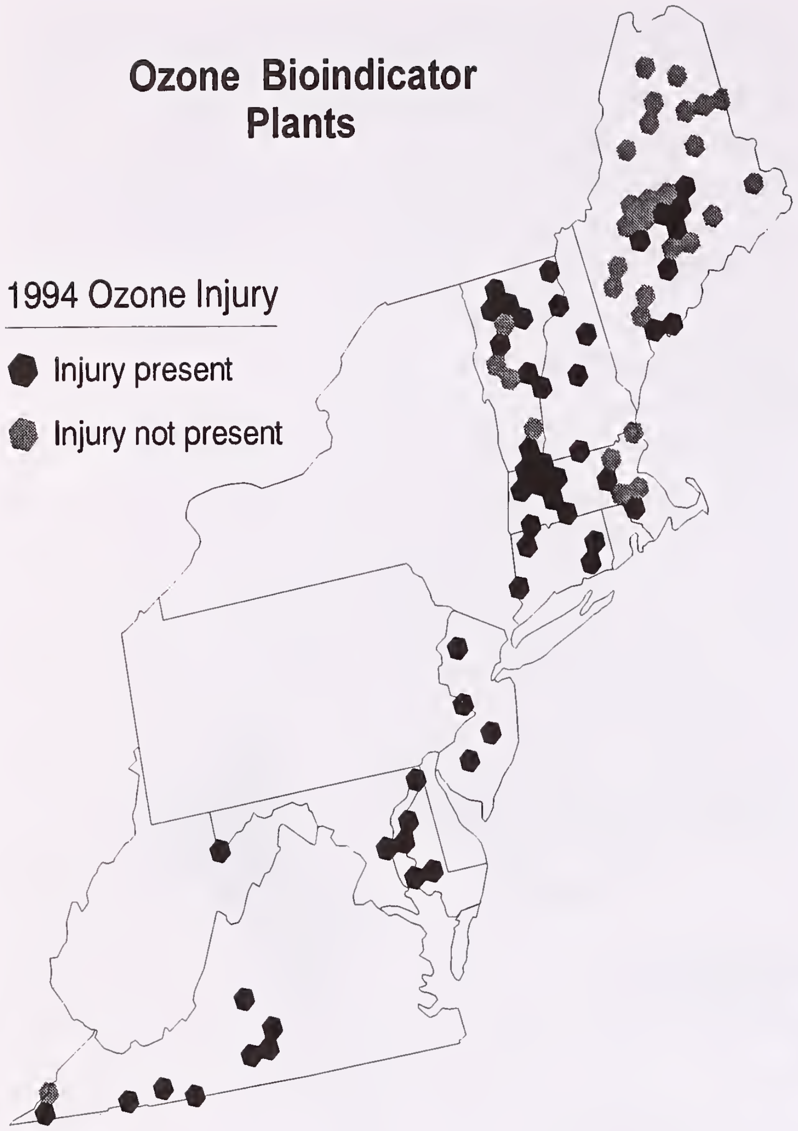

Figure 9. FHM plots with ozone-sensitive species that had one or more plants with foliar injury due to ozone in 1994.

Figure 10. Tree mortality rates of all species found on FHM plots in the eastern United States in 1993. Mortality is expressed as a percent of total basal area.

trol, information management, and assessment components of the FHM program facilitate annual reporting on forest condition. Some results from the analysis of FHM data in the eastern United States show how regional assessment of forest condition and changes can be made for crown dieback (Figure 8), ozone bioindicator plants (Figure 9), and tree mortality rates (Figure 10).

The Evaluation Monitoring component of the FHM program is in the early planning and implementation phase of development. A plan has been drafted with some general directions on procedures to follow when adverse conditions are found in areas that are greater than expected, based on historic variation or on reference sites.

The Intensive Site Ecosystem Monitoring (ISEM) component of FHM is in the later planning and early implementation phase. Several workshops have been conducted to identify core monitoring sites, core monitoring objectives and methods (Figure 2), information management approach, and management structure. Some ISEM monitoring has been funded for the core Hubbard Brook site, and some satellite sites, in the northeast United States.

The Research on Monitoring Techniques component of the program is essential to the indicator development, assessment, and statistical design components of the program. An oversight committee of FHM participants has developed methods for identifying research objectives, soliciting research propos-

als, and evaluating, ranking, and providing funding to high-ranked proposals. Ranking of research proposals is based on relevance of the project to FHM objectives, technical merit of the project, and cost. Funding support for this component of FHM needs to be stabilized so that adequate time is available to identify needs, solicit proposals, evaluate, rank, and peer-review proposals, and conduct the research in the appropriate field seasons.

The FHM program will continue to evolve as new information is needed. The FHM program is already providing a valuable insight into the condition of forest ecosystems in eastern U.S. and parts of the western U.S. Additionally, the technical and management framework has been developed for the implementation of new FHM indicators in other States and countries, and the addition of new monitoring indicators.

ACKNOWLEDGEMENTS

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Problemas Actuales, Necesidades, Oportunidades y Perspectivas en la Evaluación y Monitoreo de los Recursos Forestales en México

Sergio Varela Hernandez[1]

I. MARCO DE REFERENCIA

México es un país con una importante diversidad biológica representada en los tres principales ecosistemas que hay en el mundo, nuestro país constituye un corredor natural que une el germoplasma de dos hemisferios. Se dice que ocupamos el 4 lugar por la biodiversidad generada, situación que nos confiere especial responsabilidad de su conservación, por sus posibilidades de hibridación y evolución genética.

Se reconoce que los recursos forestales están sujetos a procesos graves de deterioro en regiones criticas y sensibles como son los trópicos.

La administración eficiente y racional de nuestros recursos, plantea exigencias de información confiable de sus características cualitativas y cuantitativas, que posibiliten una gestión articulada con su entorno social y económico y nos permita transitar al desarrollo sustentable, tema que tanto se ha enfatizado en este taller.

El Gobierno de México ha hecho esfuerzos por conocer con precisión las condiciones de nuestras selvas, bosques y semidesiertos. Diversas dependencias han elaborado estudios específicos al respecto, incluyendo acciones de investigación básica y aplicada. Destacan los trabajos de cuantificación realizadas desde 1968 por el INEGI, quien ha generado un importante acervo de información cartográfica a diversas escalas, y que en el presente trabaja digitalizándola para sistematizarla a través del Sistema Nacional de Información Geográfica.

El Inventario Nacional Forestal, dependencia de la SEMARNAP ha venido cuantificando las areas forestales desde 1960, con dos propósitos básicos: conocer el estatus del recurso, y determinar su dinámica de cambios por la acción del hombre y de la propia naturaleza.

En el primer caso, estudio del status, se han logrado avances notables. Se han desarrollado a la fecha 3 inventarios, siendo el ultimo el Inventario Forestal Periódico, que se establece como un sistema de evaluación permanente, donde toda su información esta digitalizada y cuyos principales componentes son:

- Cartografía forestal y de usos del suelo en escala 1:250 mil.
- Cartografía de zonificación (ordenamiento del uso del suelo) en igual escala.
- Base de datos del muestreo de campo de casi 20 mil sitios georeferenciados de muestreo.

II. ESTADO ACTUAL DEL MONITOREO FORESTAL

Por lo que toca al segundo rubro, de conocer la dínamica de cambios del recurso, que nos permita responder oportunamente a la presencia de factores o agentes adversos como la tala ilegal, desmontes, incendios, plagas y otros; se han tenido avances limitados en esquemas nacionales sistematizados. Se cuenta con trabajos específicos de muchas dependencias presentes aqui, sin embargo reconocemos que son trabajos aislados.

El Inventario Nacional Forestal ha recabado información sobre datos ecológicos y silvicolas, que tiene por objeto conocer los principales factores que degradan al recurso y la intensidad de ellos. Esta

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información esta disponible para los tres Inventarios realizados, tanto a nivel de todo el país como para cada Entidad Federativa

Por otra parte, el Inventario Nacional Forestal, en 1971 con la colaboracion del servicio forestal de los E.U.A., inició el Inventario Forestal Continuo del pais, que se basó en el establecimiento de sitios permanentes de muestreo, donde se remedirían cada cinco años los arboles identificados, y asi determinar los cambios ocurridos en los bosques y los factores o causas.

Los principales indicadores que se midieron y que serian comparados posteriormente fueron:

- Superficies de la cubierta forestal
- Número de arboles por especie, hectarea y rodal
- Estructura diamétrica
- Estructura de alturas
- Grosor de corteza por especie
- Frecuencia de arbolado
- Mortandad
- Area basal
- Volumen de madera
- Factores de perturbación (daño humano directo, plantas parásitas, incendios , insectos, viento, enferdedades, pastoreo, aprovechamientos, otros)
- Factores Ecológicos Silvícolas (fiografiá, pendientes, erosión)
- Estructura, forma y vigor
- Potencialidad económica (cantidad y calidad del arbolado)
- Frecuencia de repoblado
- Estructura de edades
- Crecimiento en (diámetro, altura, area basal y volumen) y
- Arboles incorporados

El esquema planteaba dos vertientes para su instrumentación:

A: Las areas concesionadas para su aprovechamiento, que serían responsables de la ejecusión del Inventaio Continuo, a través de los equipos técnicos encargados de conducir los programas de manejo silvícolas. Se estableció, por ejemplo, en Jalisco y el Estado de México.

B: El Gobierno Federal se encargaría de establecer la red de sitios permanentes de muestreo y aplicar el sistema en general en las selvas, bosques y zonas áridas,que no estuvieran bajo concesion de aprovechamiento forestal. El IFC. se estableció en bosques de Chihuahua, Durango y Sonora.

En su mayoría el programa no pudo continuar por razones de reorientación de poíiticas, restricciones presupuestales y modificaciones a la Ley Forestal

III. PUNTOS COMUNES DE MONITOREO CON OTROS ECOSISTEMAS

En los últimos diez años, el tema de la deforestación ha ocupado un primer plano, por su impacto en la degradación de los ecosistemas y recursos asociados como el suelo, la vegetación, el agua, la fauna y el paisaje. De manera mas general, preocupa su impacto en los cambios climáticos y en el efecto invernadero, ademas del elevado costo social y económico por el uso irracional del recurso, que se enfatiza de manera crítica en los paises en desarrollo

El estudio de la deforestación en México se ha hecho por diversas dependencias, instituciones y organismos. Los procedimientos, críterios y conceptos utilizados en todos los casos han sido diversos, dando como resultados que existan cifras muy disímbolas sobre la superficie que se deforesta en el pais, que van desde 230 mil ha., hasta 1.5 millones de ha. al año.

El Inventario Nacional Forestal ha realizado estimaciones comparando cartografía de diversas épocas y conjuntando información de campo de las Delegaciones de la SEMARNAP en los Estados. Se analizaron como principales factores del deterioro los siguientes:

- Desmontes ilegales para usos agrícolas y ganaderos no estabilizados.
- Cambios de uso del suelo autorizados para infraestructura básica (caminos, presas, líneas eléctricas, centros de población y otros).
- Incendios, plagas y enfermedades.
- Siniestros (ciclones, nortes y otros).
- Tala ilegal, que incluye uso doméstico (leña y autoconstrucción)

Se tienen estimaciones de la intensidad de estos factores adversos y de su participación porcentual en la deforestación; sin embargo, podremos tener las cifras reales del fenomeno hasta que comparemos, dentro de cinco años, la cartografía actualizada del Inventario Forestal Periódico. Por lo pronto se realiza un estudio de cambios con imágenes Landsat TM, mediante un muestreo de escenas para los tres ecosistemas donde participan las dependencias y organismos que han estudiado la deforestación a fín de obtener un concenso sobre cifras, índices y factores de perturbación.

El tema de la deforestación debe ser abordado y auxiliado de manera prioritaria por esquemas de monitoreo de ecosistemas. Tambien se debe dar seguimiento puntual a los planes rectores de usos de la tierra, como un instrumento para detener los cambios de uso del suelo forestal.

A este respecto, En México se han realizado estudios para definir la frontera agrícola, ganadera y forestal. Sin embargo se reconoce que las actividades agropecuarias se han expandido a costa de los terrenos forestales, por lo que es urgente la instrumentación de estudios que ha realizado la SEMARNAP sobre ordenamiento ecológico territorial y zonificación forestal. Estos estudios son instrumentos de planeación indicativa, que orientan sobre el uso mas adecuado que debe darse al terreno tomando en cuenta las aptitudes de los recursos y sus funciones ambientales. Asi, se han delimitado aquellos que pueden incorporarse a procesos productivos, cuales se deben proteger y conservar, y cuales deben someterse a trabajos de restauración. Tambien se han identificado los terrenos cuyo uso actual es agrícola y ganadero marginal de bajos rendimientos, que se recomienda reconvertirse al uso forestal.

Una de las principales líneas de política de la presente administración, es frenar el deterioro de los recursos naturales. Solo con ello se podran concretar acciones de sustentabilidad. Se busca tambien revertir las tendencias de la degradación e iniciar la restauración y desarrollo de los bosques, selvas y semidesierto. Para ello la SEMARNAP cuenta con diversos programas y acciones como son: El control y prevención de la deforestación, los incendios, las plagas y enfermedades, el PROAFT, las acciones de supervición y vigilancia de la PROFEPA tanto para los aprovechamientos autorizados asi como para las actividades de prevención y sanción por agresiones a los ecosistemas forestales. Por lo que toca al recurso suelo, se han intensificado las actividades para su conservación y restauración, previendose acciones específicas en contra de la erosión y desertificación. El sequimiento, evaluación y corrección de los programas respectivos requiere del apoyo definitivo del monitoreo.

La SEMARNAP esta en proceso de establecimiento del SIDIA (Sistema de Indicadores Ambientales), cuyo esquema de desarrollo es el de relacionar los principales problemas que deterioran a los recursos naturales la intensidad de dicho deterioro en que condiciones se encuentran que se esta haciendo para recuperarlos y protegerlos y cual es la respuesta de los recursos a la aplicación de los programas y acciones institucionales para frenar y revertir su degradación.

IV. ATENCION A NECESIDADES DE INFORMACION

Para la instrumentación del SIDIA y la planeación de programas y ejecución de acciones en lo forestal, el Inventario Nacional de Recursos Naturales, que esta en proceso de integración y que se estructura de los recursos del Inventario Nacional Forestal,ha cubierto en parte las necesidades de información y materiales. El Inventarion Nacional Forestal Periódico, es un instrumento de planeación que se establece como una plataforma básica que requiere actualizarse permanentemente, y que sera fundamental para crear el sistema nacional de monitoreo. Requiere tambien de un laboratorio de computo que le de autonomia para mejorar la calidad de la información y el enriquecimiento de su base de datos con nuevas capas temáticas, a traves del SIG. creado exprofeso para este Inventario. La estructura de los casi 20 mil sitios de muestreo son analizados comparandolos con la "Guia Internacional para el levantamiento de información de campo para el Monitoreo Forestal" a fin de adecuarlos con ese propósito. En este rubro la cooperación Internacional es definitiva.

La SEMARNAP a través del Inventario Nacional de Recursos Naturales ha iniciado el Inventario de Suelos del País, asi como la delimitación de la zona federal marítimo terrestre, y su ordenamiento territorial por aptitudes y funciones ambientales. Se trabaja en el sistema Nacional de Indicadores Forestales y en

el establecimiento del centro de información Geográfica que nos permita satisfacer de una mejor manera los requerimientos de información de los usuarios.

La experiencia en la ejecución del Inventario Nacional Forestal Periódico, nos enseño que si es posible lograr la participación concertada. Dicho Inventario se realizó gracias a la cooperación Inernacional, el apoyo de la UNAM, INEGI, EL IMTA, y de manera notoria por la participación de los Gobiernos estatales que se responsbilizaron de los muestreos de campo, y quienes recurrieron, en muchas ocasiones a la colaboración de productores e industriales locales para poder sufragar los trabajos. Con esto quiero ilustrar la disposición que existe por el estudio y mejor manejo de nuestros recursos por parte de los sectores vinculados, que a la vez son usuarios de la información. La actual situación de crisis del país debe tomarse muy encuenta en los procesos de negociación de apoyos.

V. PROBLEMAS ACTUALES PARA DESARROLLAR EL MONITOREO

Entre los problemas mas comunes que se tienen en México para el registro y seguimiento continuo de información sobre las condiciones de los ecosistemas tenemos los siguientes:

- Las estadísticas existentes sobre factores y parámetros de afectación de Ecosistemas Terrestres y Acuáticos, se encuentran dispersas en las diversas areas y dependencias.
- En lo referente a los ecosistemas forestales, en general se requieren apoyos en cuanto a infraestructura, equipo, materiales, instrumentos, capacitación de personal y financiamiento para el Monitoreo.
- Hay un incipiente desarrollo en la sistematización a nivel Nacional y Regional al respecto.
- Se tienen experiencias y desarrollo de investigaciones aisladas.
- Se cuenta con una base Cartográfica Nacional Forestal y un banco de información de campo que puede constituir la base de un sistema de monitoreo a nivel país.

VI. NECESIDADES Y OPORTUNIDADES PARA EL MONITOREO

- Es conveniente identificar una dependencia u órgano rector que norme, coordine, globalice, estandarice y evalúe los procedimientos, métodos y sistemas de monitoreo en los diferentes niveles, que cuente con capacidad técnica y legal para realizar sus funciones.
- Se requieren de sistemas de control de calidad que garanticen la confiabilidad de la información y de los reportes sobre monitoreo.
- Es necesario hacer una revisión de los indicadores de perturbación, para establecer los límites permisibles de degradación a causa de factores como incendios, plagas, daños por erosión, tala, contaminación y deforestación, entre otros.
- Se debe realizar un esfuerzo por estandarizar la cartografía generada por diversas Dependencias, para sumarse al sistema Nacional de Información geográfica del INEGI.

\- Es necesario contar con una estación terrena alterna o de un contrato con EOSAT para la adquisición de imágenes de satélite necesarias para el monitoreo de Ecosistemas Acuáticos y Terrestres, para todo el sector público.

- Debe plantearse la participación de los gobiernos de los estados en actividades de evaluación y monitoreo, con la directriz y normatividad de las instituciones federales vinculadas, como INEGI, PROFEPA, Y SEMARNAP.
- Se debe buscar que el monitoreo apoye la instrumentación del ordenamiento del uso del suelo a fin de que ya no se reduzca la frontera forestal.
- Es necesario generar normas y lineamientos comunes a nivel nacional, y para algunos casos a nivel internacional que nos permitan sumarizar y estandarizar resultados para la toma de decisiones comunes.
- Se requiere incrementar y reforzar la cooperación nacional e internacional a través del intercambio de experiencias, asesoría

técnica, capacitación, y financiamiento. Para ello se propone la creación de un grupo norteamericano de trabajo sobre monitoreo. Previamente deberá crearse el grupo a nivel Nacional sobre el tema, que registre las actividades que se desarrollan por diversas dependencias y propicie, en lo posible, la coordinación de esfuerzos para optimizar recursos y obtener mejores resultados.

Sediment Core Studies in the Assessment of Contamination of Surface Waters

Lyle Lockhart, Paul Wilkinson, Brian Billeck, Robert Danell, Robert Hunt, Rudolf Wagemann, Derek Muir, and Gregg Brunskill[1]

INTRODUCTION

Chemical pollution near point sources has become commonplace. Trace chemical contamination has reached even the most isolated parts of the planet, often as a result of human activities conducted at great distances from the places where the contaminants are reported. With purely synthetic compounds there is no natural source and so their presence alone indicates human activity. For example, detection of DDT in snow from the Antarctic (Peterle, 1969) was one of the early indications of the tendency of that compound to become widely distributed in the environment. When other materials such as metals and polycyclic aromatic hydrocarbons are found, both natural and anthropogenic sources may have contributed. In these cases it is often desirable to partition the amount found into a component due to nature and one due to human activities because the latter, at least in principle, can be controlled. Efforts to understand changing inputs of chemicals and to apportion them to different sources have lead to the examination of integrating media like glacial snow, peat bogs, tree rings, soils and lake sediments. In this presentation, sediments only will be discussed.

Cores from lake sediments have often been used to reconstruct cultural and environmental histories of the drainage basins (e.g. Hutchinson, 1970; Haworth and Lund, 1984). Over the past two decades a number of papers have appeared describing histories of chemical contamination inferred from sediment core profiles. For example, Smith and Loring (1981) showed that sediments from the Saguenay fiord in eastern Canada recorded of releases of mercury from a local chloralkali plant. Several investigators have studied cores from lakes in central North America and found that rates of input of mercury are about triple the natural rates (Evans, 1988; Rada et al., 1989; Swain et al. 1992), even when there are no sources within the drainge basins. Gschwend and Hites (1981) reported similar results with polycyclic aromatic hydrocarbons (PAHs). Sediment cores recorded increasing inputs of PAHs until the mid 20th century followed by a subsequent decline in recent decades. One explanation for this pattern is the change in home heating fuel in central North America from coal to oil and natural gas during the 1940s and 1950s. Sediments have also recorded inputs of synthetic organochlorine compounds like PCBs and chlorinated dioxins and furans (Eisenreich, 1989; Macdonald et al., 1992). Perhaps the most persuasive example is the pattern of cesium-137 in sediments. This isotope originated from testing nuclear bombs and it is found so reliably in lake sediments that its peak in the sediment column can be used to date the layers. These and numerous other studies leave little doubt that sediments can and often do preserve records of changes in inputs of a number of stable chemicals. Applications of this approach have been reviewed recently by approach has been reviewed recently by Valette-Silver (1992).

The great advantage offered by sediment studies lies in their ability to estimate actual loading rates. When the time interval over which a slice was deposited can be determined, the weight of material deposited over that time is determined, and the surface area of the core tube is known, then the sedimentation rate in terms of weight per time interval per area for the site is obtained. When the slices are then analyzed for various contaminants, the concentration of each contaminant is obtained then the rate of

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net input of each can then be calculated as the product of the sedimentation rate and its concentration. The success of the approach in the cases cited below is not to say that sediments always preserve accurate records since a variety of physical, chemical and biological processes can act to obscure the records.

We have been using lake sediments in efforts to understand contamination of fish and aquatic habitat in isolated areas of Canada, remote from local industrial sources or centres of population. For example, numerous lakes in northern Canada contain fish with concentrations of mercury above that taken to be acceptable for human consumption and the question arises whether the contamination is due to the natural geology of the drainage basins or to human activities. There are persuasive arguments that industrial emissions of mercury have increased over the last century or so as a result largely of burning coal and municipal garbage (Nriagu and Pacyna, 1988). There are also persuasive arguments showing that some chemicals emitted as far away as Eurasia are deposited to northern Canada by atmospheric fallout (Welch et al.1991, Lockhart et al., 1993; Kidd et al. 1995). There are also well known concentrations of mercury in the geology of many lake basins throughout Canada (Painter et al., 1994). Hence a solution for a 'nature vs. pollution' problem is needed.

METHODS

Core handling Lake sediment cores have been taken either from ice during winter or from small boats or large ships during the open-water season (Lockhart et al., 1993). For lakes discussed here we have used a 10-cm KB-type corer (Mudroch and MacKnight, 1991) or a larger stainless steel box corer. For large bodies of water we have used an oceanographic box corer and then taken 10-cm push cores from the box of sediment on the deck of the ship. Cores have been sliced, usually at 1-cm intervals, at the time of collection and individual slices stored in Whirlpakâ bags until transported back to the laboratory and analyzed. Sediments were stored at 4°C or as near to that temperature as possible during field storage and transport. Upon arrival at the laboratory they were maintained at that temperature. Subsamples of fresh material were taken for studies of algal remains and the balance was freeze dried. The freeze dried weight was taken as the dry weight of sediment.

Data from five lakes are presented (Table 1): Lake 375, a small lake in the precambrian sheild/boreal forest area of northwestern Ontario, Hawk Lake, a small lake located on precambrian shield/tundra of the west coast of Hudson Bay, Far Lake, a very small lake located near Hawk Lake, Buchanan Lake, a large, poorly known glacier-fed lake on Axel Heiberg Island in the high Arctic, and Lake Kusawa, a large river-like lake in the mountains of the southern Yukon Territory. Bathymetric information was available for all but Buchanan Lake, and core sites were selected in deep areas where sediments would be expected to be trapped.

Lead-210 and cesium-137 Radioactive isotopes were counted as described by Lockhart et al. (1993). A subsample of each slice was counted on a gamma spectrometer using a hyper-pure germanium crystal to determine Be-7, Cs-137 and Cs-134. Then 1-2 g aliquots of each slice were analyzed for Pb-210 and Ra-226. The samples were leached at 80°C with nitric and hydrochloric acids with a known amount of Po-209 present as a tracer. Polonium was then autoplated onto a silver disc from 1.5 N HCL (Flynn, 1968). The disc was counted on an alpha spectrometer using a silicon surface barrier detector and Pb-210 was determined as the activity of its daughter, Po-210. The remaining solution was placed in a sealed radon

Table 1. Locations and some limnological features of lakes.

Lake	Latitude	Longitude	Lake area (ha)	Watershed area (ha)	Sedimentation ($g\ m^{-2}\ y^{-1}$)	Mean depth (m)	Max depth (m)
Lake 375	49° 45	93° 47	18.7	210	235	11.6	30
Hawk	63° 38	90° 42	24.3	299	47	11.7	34
Far	63° 42	90° 40	3.7	16.6	101	3.6	8.9
Buchanan	79° 30	87° 30	1800	39400	-	-	-
Kusawa	61° 21	136° 12	14200	-	-	54	140

bubbling bottle and analyzed for Ra-226 by the radon de-emanation method (Mathieu, 1977). The error in counting replicate samples for Pb-210 in this way was under 8 per cent.

The initial analyses were for lead-210 and cesium-137 to derive estimates of the time interval when each slice was deposited. Time intervals of deposition, and hence the estimated age of each slice, were calculated using mixing models supplied by Dr. John Robbins, NOAA, Ann Arbor, Michigan. The maximum age we can estimate using lead-210 is about 150 years before the present time. If profiles of lead-210 and cesium-137 indicated datable sequences, then the slices were taken for analyses of contaminants.

Mercury For the analysis of mercury in each slice, 0.1 - 0.5 g of freeze dried sediment was heated to gentle boiling with 8 mL aqua regia and made to 50 mL with distilled water (Dow Chemical of Canada, Ltd., Method CAS-AM-70.13). Mercury was determined in the supernatant by cold vapour atomic absorption (Hendzel and Jamieson, 1976). National Research Council of Canada marine analytical reference sediments were analyzed concurrently.

Lead Samples of freeze dried sediment were digested with nitric, perchloric, hydrofluoric and sulfuric acids in teflon beakers; final volumes were adjusted to 25 mL. Lead was analyzed in the digests by flame atomic absorption specroscopy. Samples for mercury required a separate digestion with aqua regia. National Research Council of Canada standard reference sediments were analyzed concurrently with sediment samples as a measure of analytical quality.

Cadmium Cadmium was analyzed by graphite furnace atomic absorption on the same digest used for lead.

PAHs Freeze dried sediment which was soxhlet extracted with dichloromethane (DCM) (Giger and Schaffner, 1978; McVeety and Hites, 1988) and sulfur was removed by passing the DCM extract through activated copper powder. The DCM extract was then evaporated under reduced pressure and taken up into hexane. The hexane extract was split with half being taken for PAH analysis and half for organochlorine analysis. A standard solution containing 100 ng of each of seven deuterated PAHs was added to each sample of the portion taken for PAH analysis, and the extract was fractionated on silica/alimina columns, (Boehm 1983). PAHs were chromatographed on a bonded phase, 30 m x 0.25 mm, J & W, DB-5 fused silica, capillary column and measured by GC/MSD using a multiple internal standard method (Fisk *et al*, 1986; McVeety and Hites, 1988), with the MSD in the single ion monitoring mode.

Figure 1. Map showing locations of the five lakes under discussion.

Organochlorines

The same sample of freeze dried sediment used for PAH analyses was also used to determine organochlorines. Sediments were fortified with standard solutions of aldrin and octachloronaphthalene prior to soxhlet extraction with dichloromethane. After removal of sulfur and exchange into hexane the portion of the extract to be used for organochlorine analysis was partitioned on florisil (Muir et al., 1988) and analyzed by gas chromatography using a Ni-63 detector with confirmation of selected samples of major pesticides by GC/MS (Hewlett Packard 5971 MSD) and confirmation of chlorinated bornane (toxaphene) peaks by GC/MS (Kratos Concept HRMS) using electron capture negative ion mode (Stern et al., 1992).

RESULTS AND DISCUSSION

Lead-210 and cesium-137 in lakes

Profiles of lead-210 and cesium-137 for cores taken from three lakes, Lake 375 at the Experimental Lakes Area of northwestern Ontario, and Far Lake and Hawk Lake, both on the west coast of Hudson Bay, are shown in Figure 2. In all instances the plots of excess lead-210 (plotted on the top scale in exponential units) against accumulated dry weight show regular declines with increasing depth, suggesting datable sequences. The date scale shown at the left of each figure is derived from the lead-210 profile calculated using mixing models supplied by Dr. John Robbins, NOAA, Ann Arbor, MI. Considering the cesium-137 profiles, we should expect to find the peak activity in the mid-1960s coincident with peak bomb testing and our confidence in the lead-210 dates and these cores have peak Cs-137 at about the expected depths. An unusual feature of the Far Lake core was the higher Cs-137 in the top slice than in the second slice. We have no good explanation for that other than the possibility of some input from Chernobyl. Both Hawk and Far lakes were sampled in 1988, and both had traces of Cs-134 in the top slice indicating a measurable input from Chernobyl.

Unfortunately, in spite of careful sampling and analyses, lead-210 profiles are sometimes not as readily interpreted as those in Figure 2. For example, the lead-210 profile shown in Figure 3 was obtained on a core taken from Buchanan Lake, Northwest Territories. The excess lead-210 was variable but showed no indication of the expected exponential decrease with depth. Cesium-137, however, did show a typical pattern with a relatively sharp peak several cm deep in the core. Hence the two isotopes failed to agree and we are not confident in estimating the time intervals for deposition of slices at this site. There is no bathymetric data for this lake, and the corer may have penetrated a slope rather than a flat bottom.

Mercury in Datable Cores

Most of our core slices have been analyzed for mercury because it is often elevated in edible tissues of fish from northern Canadian lakes. Some of these have been presented elsewhere (Lockhart et al, 1992; 1993; 1995). Figure 4 shows profiles of mercury in

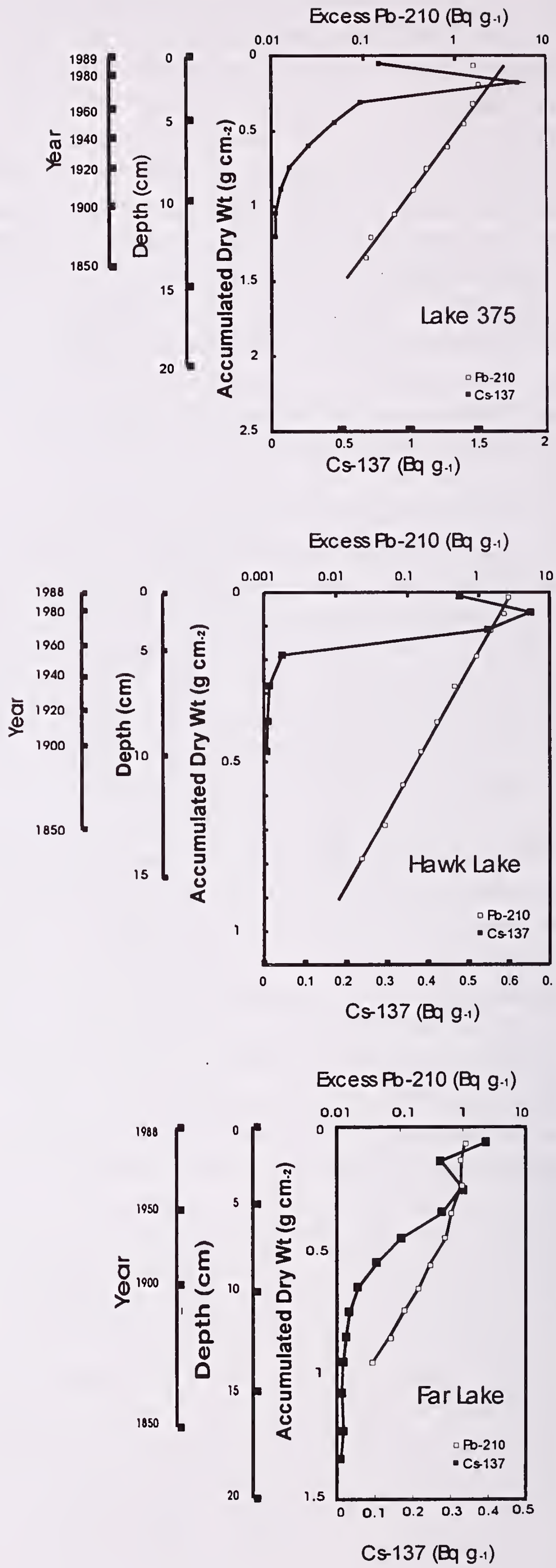


Figure 2. Lead-210 and cesium-137 profiles.

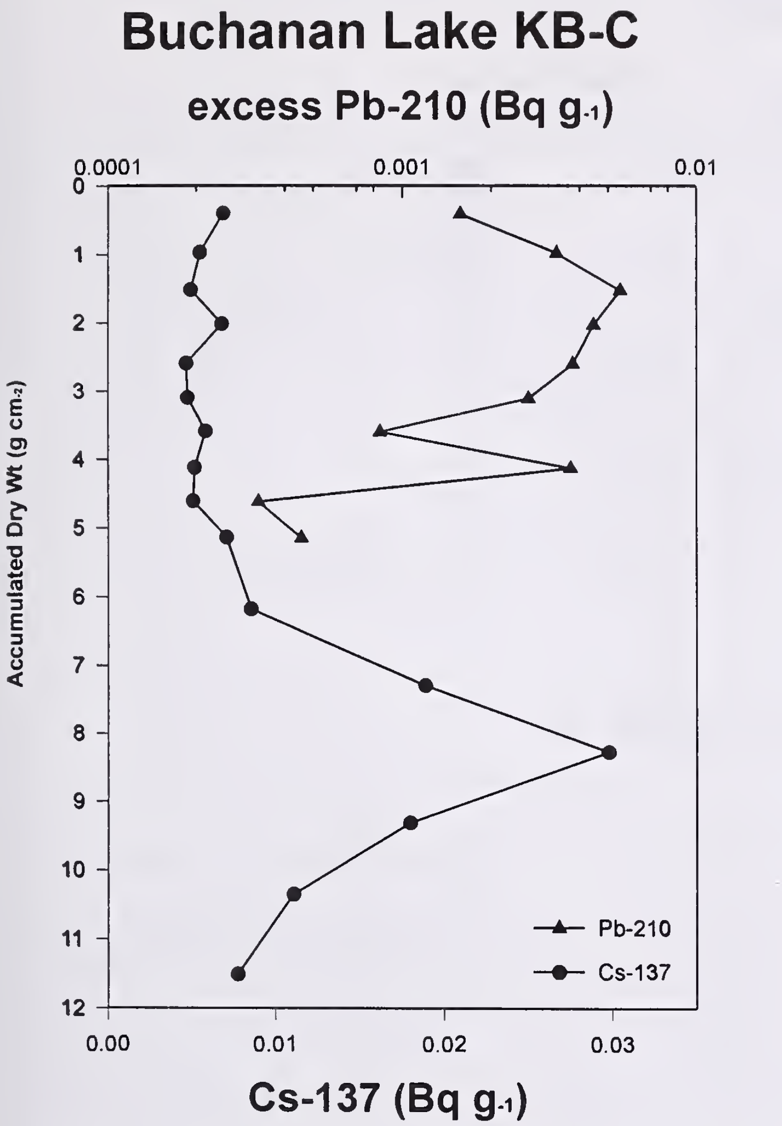


Figure 3. Lead-210 and cesium-137 from Buchanan Lake, N.W.T.

sediments of Lake 375 and Hawk and Far Lakes. In all three instances the uppermost slices contain strikingly more mercury than the lower ones. Loadings are lower to the more northern lakes than to the southern one, but the pattern of recent increases is evident in all of them. Furthermore, there is no indication that mercury loadings have decreased in recent time as polycyclic aromatic hydrocarbons appear to have done.

Recently, the interpretation of cores suggesting increased inputs of mercury has been questioned (Rasmussen, 1994). The usual interpretation of increases in upper slices relative to lower ones is that they reflect increased loading during more recent time. We have been trying to resolve this conflict in interpretations using several approaches. One hypothesis we entertained was that the pattern shown by mercury might be an artifact of gradients in organic carbon. Figure 4 shows the organic carbon in the same cores as the mercury, and it is apparent that mercury and organic carbon behave independently. Lake 375 and Far Lake show essentially no change in organic carbon with depth, but both show distinct elevations in mercury in the top slices. The mercury and organic carbon

profiles are superfically similar in Hawk Lake, but the fall in mercury concentrations with depth is more recent than the fall in organic carbon concentrations. Another possibility was that profiles shown by mercury were generated by geochemical gradients within the sediment column; these gradients are responsible for the concentration of some other elements, notably iron and manganese, near the sediment/water interface. Most of our cores have been analyzed for iron and manganese, but there are no correlations between patterns shown by mercury and those shown by iron or manganese. Cores have been used widely in Scandinavia and Alaska for estimating deposition of mercury (Johansson, 1985, Verta et al., 1988; Gubala et al, 1995) with conclusions generally similar to those presented here.

We have just completed a core from Clay Lake, Ontario, downstream from a chloralkali source that ceased discharging mercury in 1970. A core taken in 1971 showed the peak at the surface and a second core taken in 1978 showed the mercury a few cm below the sediment water interface. The third core just completed in 1995 showed the peak buried deeper yet. Taken together these cores show burial of the mercury with no indication that the peak migrated toward the surface. We conclude that the most probable explanation for the increases in mercury near the surface of sediments is increased loadings; the only plausible source of increased loadings to the isolated locations represented in Figure 4 is the atmosphere. Mercury concentrations in the atmosphere appear to be increasing (Slemr and Langer, 1992) and so increased loadings to lakes might be anticipated.

Cadmium in Datable Cores

Cadmium is of interest because of emissions from smelting industries in Canada. It is found at relative high levels in kidney of marine mammals in Hudson Bay and in some other large game animals. The core taken from Lake 375 at the Experimental Lakes area showed a large increase in cadmium starting in the mid-1800s and continuing until the mid-1900s (Figure 5). Present inputs are still about 5 times higher

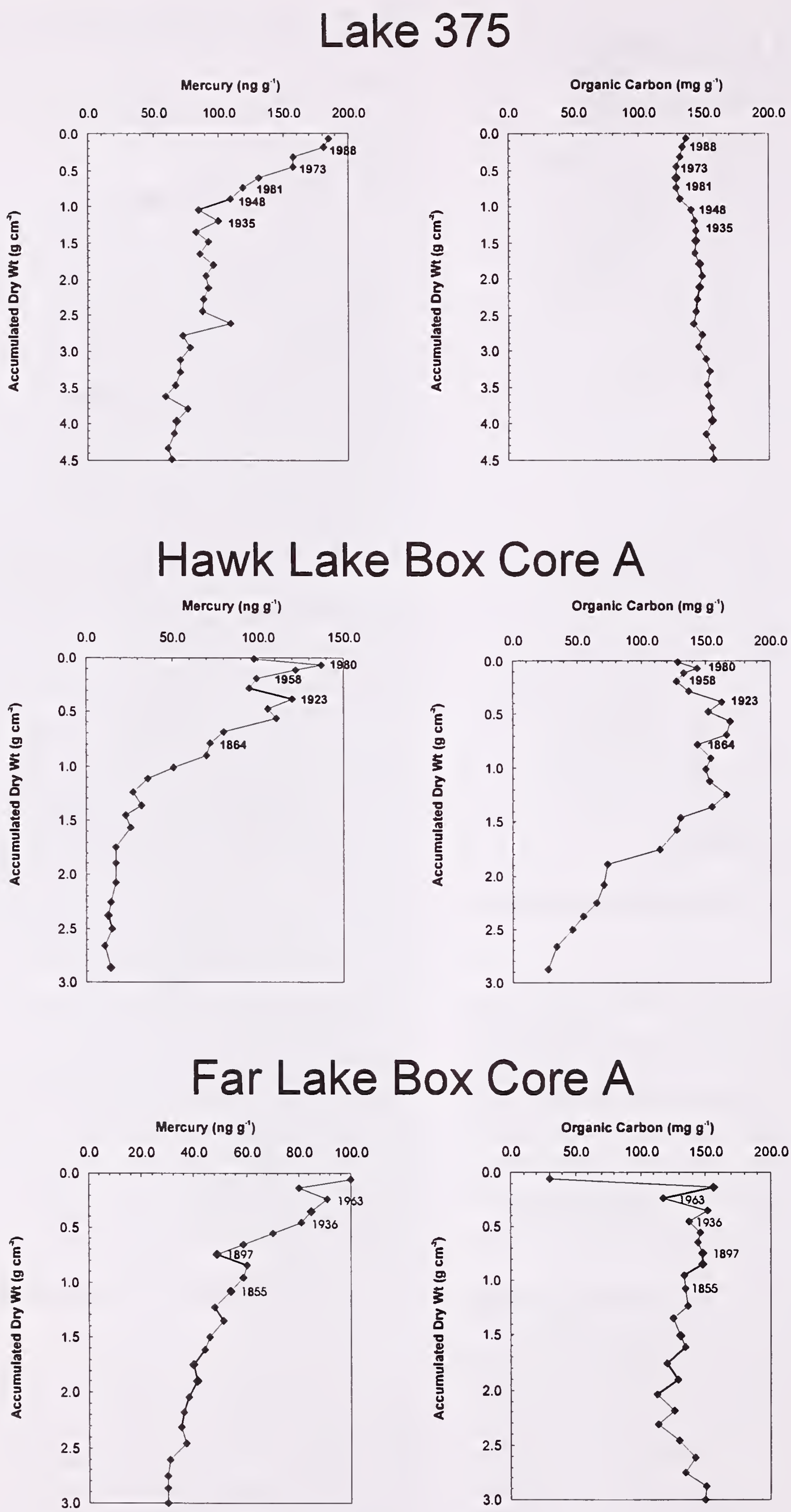


Figure 4. Mercury (left) and organic carbon (right) in sediment cores from Lake 375, Hawk Lake and Far Lake.

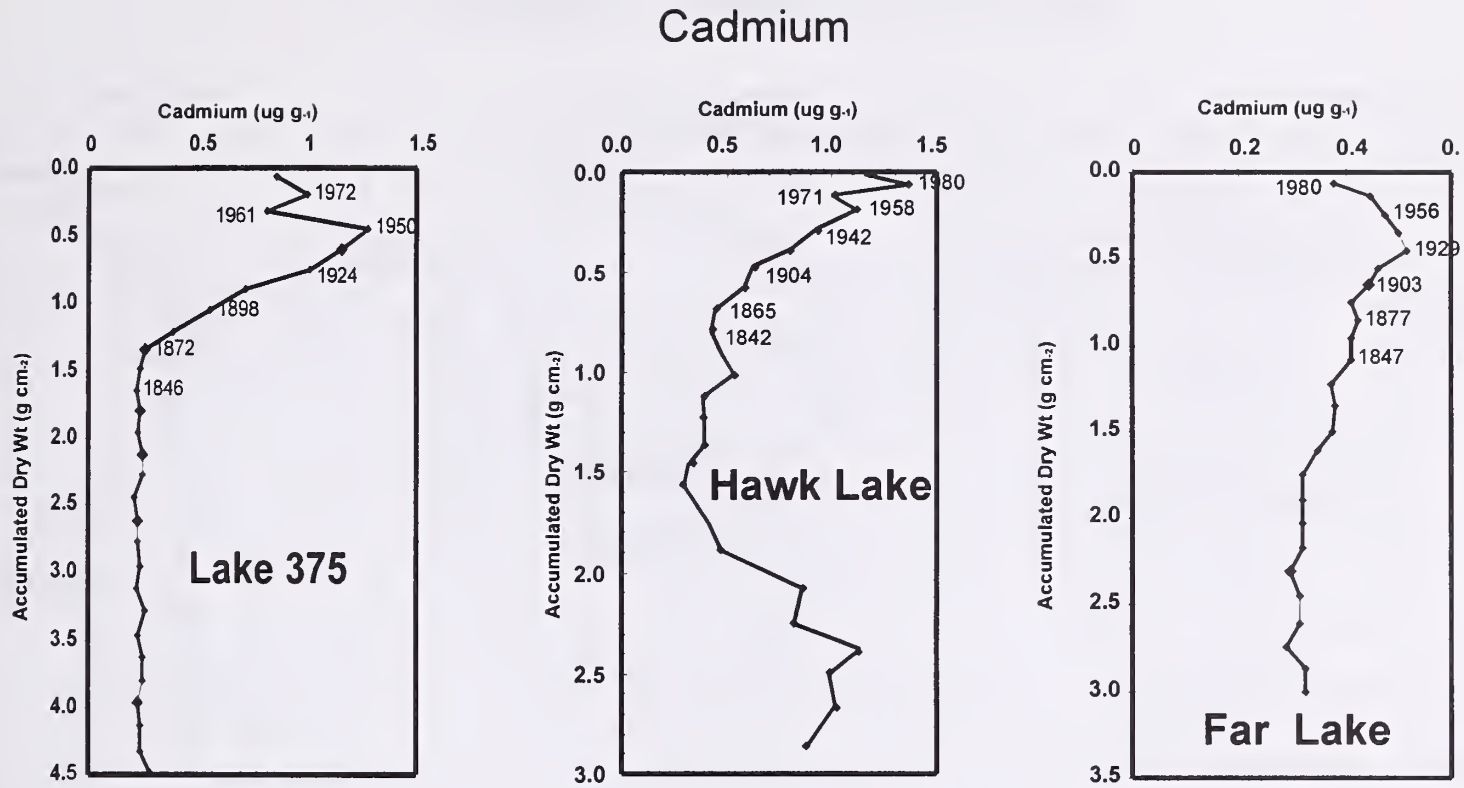


Figure 5. Cadmium in sediment cores from Lake 375, Hawk Lake and Far Lake

than pre-settlement times, but they have fallen below peak inputs. Johnson (1987) also detected increases in cadmium in recent sediments in lakes at the Experimental Lakes Area. While the sources of increases inputs of cadmium cannot be identified, potential sources seem likely to include fallout from large-scale metal smelting activities in Ontario and Manitoba. Far Lake, on the west coast of Hudson Bay, shows a pattern somewhat similar to Lake 375 but with a much less pronounced increase over basal geological levels. At Far Lake the excess of current inputs over historical inputs is only a small factor of 1.6. Hermanson (1991, 1993) also reported small increases in sediments from a shallow lake on the Belcher Islands in southern Hudson Bay The cadmium record of Hawk Lake is similar to the others from the mid-1800s to the present, but it shows a large, unexplained peak of cadmium in the lower slices. The lower slices of this lake were unusual in a number of regards.

Lead in Datable Cores

Lead typically shows increases in the upper layers of cores due to the use of leaded gasolines. All three cores showed the expected increase in upper layers (Figure 6), but again the lower slices of Hawk Lake showed an unexpedted increase. Several studies have suggested that inputs of lead have begun to decline as a result of the conversion from leaded to unleaded gasoline in North America (Boutron), but only the core from Lake 375 suggests that here.

Polycyclic Aromatic Hydrocarbons in Datable Cores

The 'total' for PAHs has been caclulated as the sum of the concentrations of the following hydrocarbons:

naphthalene	acenapthylene	acenaphthene
fluorene	phenanthrene	anthracene
fluoranthene	pyrene	benzo(a)anthracene
chrysene	benzo(b)fluoranthene and benzo(k)fluoranthene	
	benzo(a)pyrene	
indeno(1,2,3-cd)pyrene	dibenzo(a,h)anthracene	
benzo(ghi)perylene		

Perylene generally increased with depth in cores, presumably as a result of synthesis *in situ*, and so it was not included in the total. Core chronologies for the sums of these hydrocarbons in Lake 375 and Hawk Lake (Lockhart et al., (1993) and Far Lake are shown in Figure 7.

Lake 375 and Hawk Lake both show a long basal periods with levels generally under 200 ng/g followed by a striking increase starting in the mid 1800s. Concentrations continued to increase until the middle

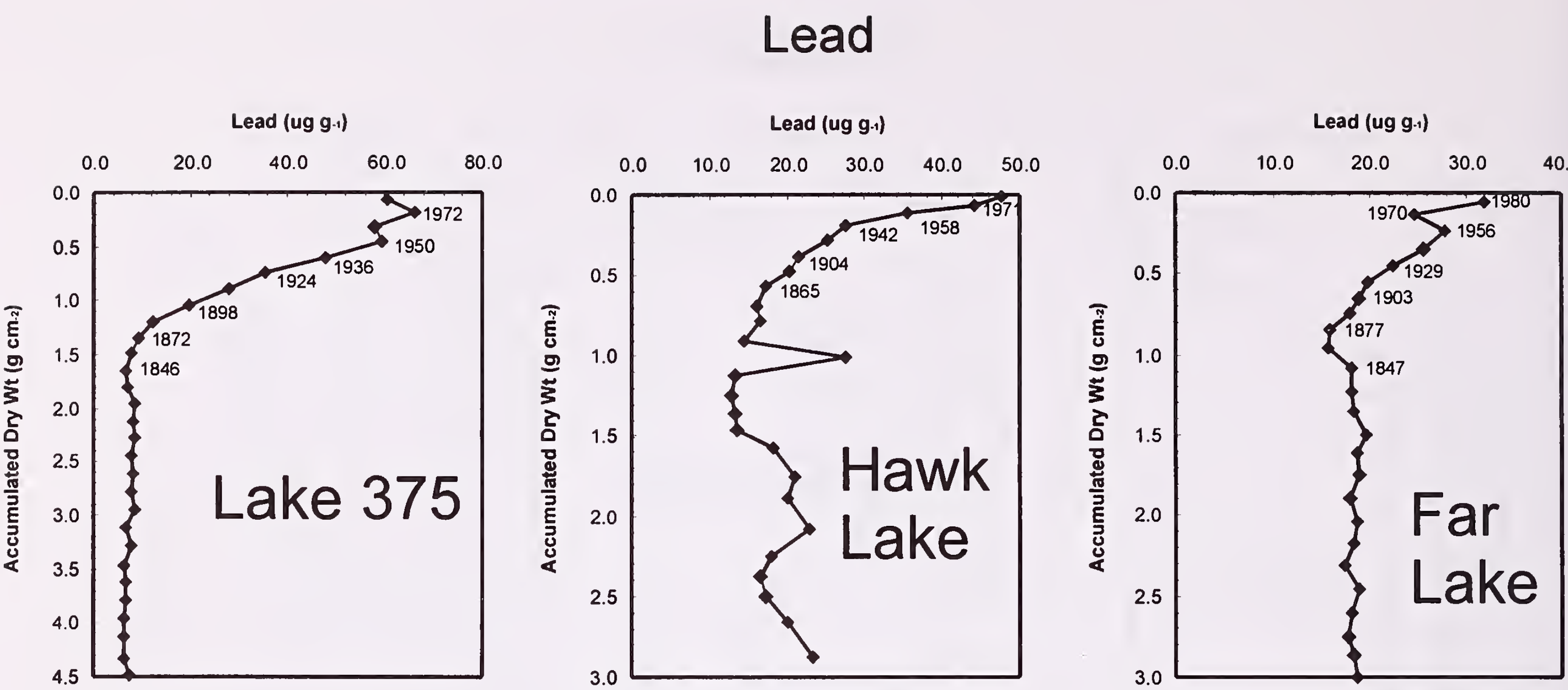


Figure 6. Lead in cores from three lakes.

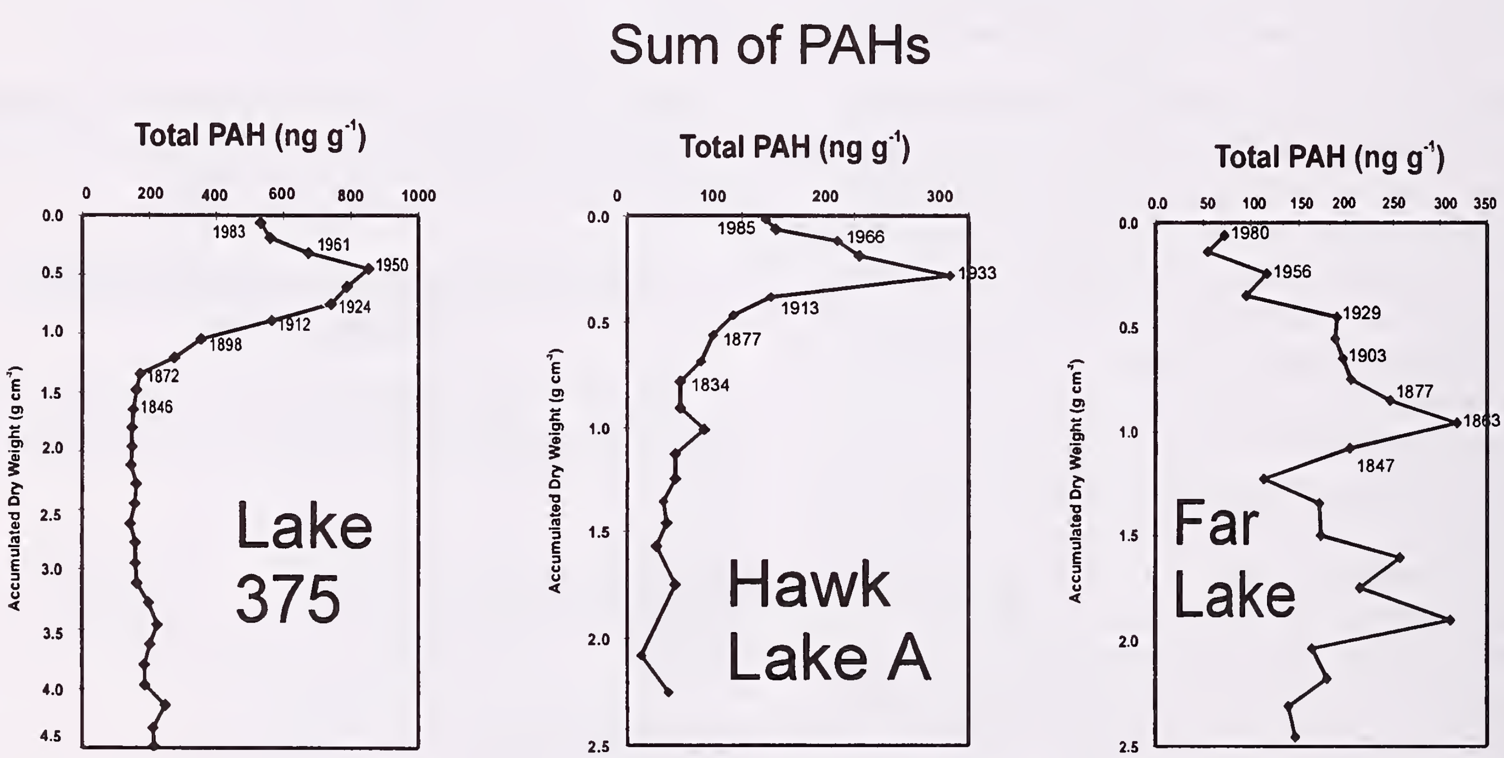


Figure 7. Profiles of polycyclic aromatic hydrocarbons for Lake 375, Hawk Lake and Far Lake.

years of the present century when peak values were reached. These have subsequently declined to values around but are still well above the basal levels. Similar data for Far Lake are also shown and there is no consistent pattern evident other than a decline in PAH concentrations over the past century and a half. The pattern at Far Lake is inconsistent with those of either Lake 375 or Hawk Lake, and Hawk Lake is only a few km distant from Far Lake. The basal values for deep slices from Hawk Lake were generally under 50 ng/g while deep slices from Far Lake were highly variable over a range from about 120 ng/g to over 300 ng/g. Slices deeper than 18 cm from Hawk Lake formed a gel during extraction, and satisfactory analyses were not obtained for most of those deep slices. However, Far Lake extractions appeared normal and wh have

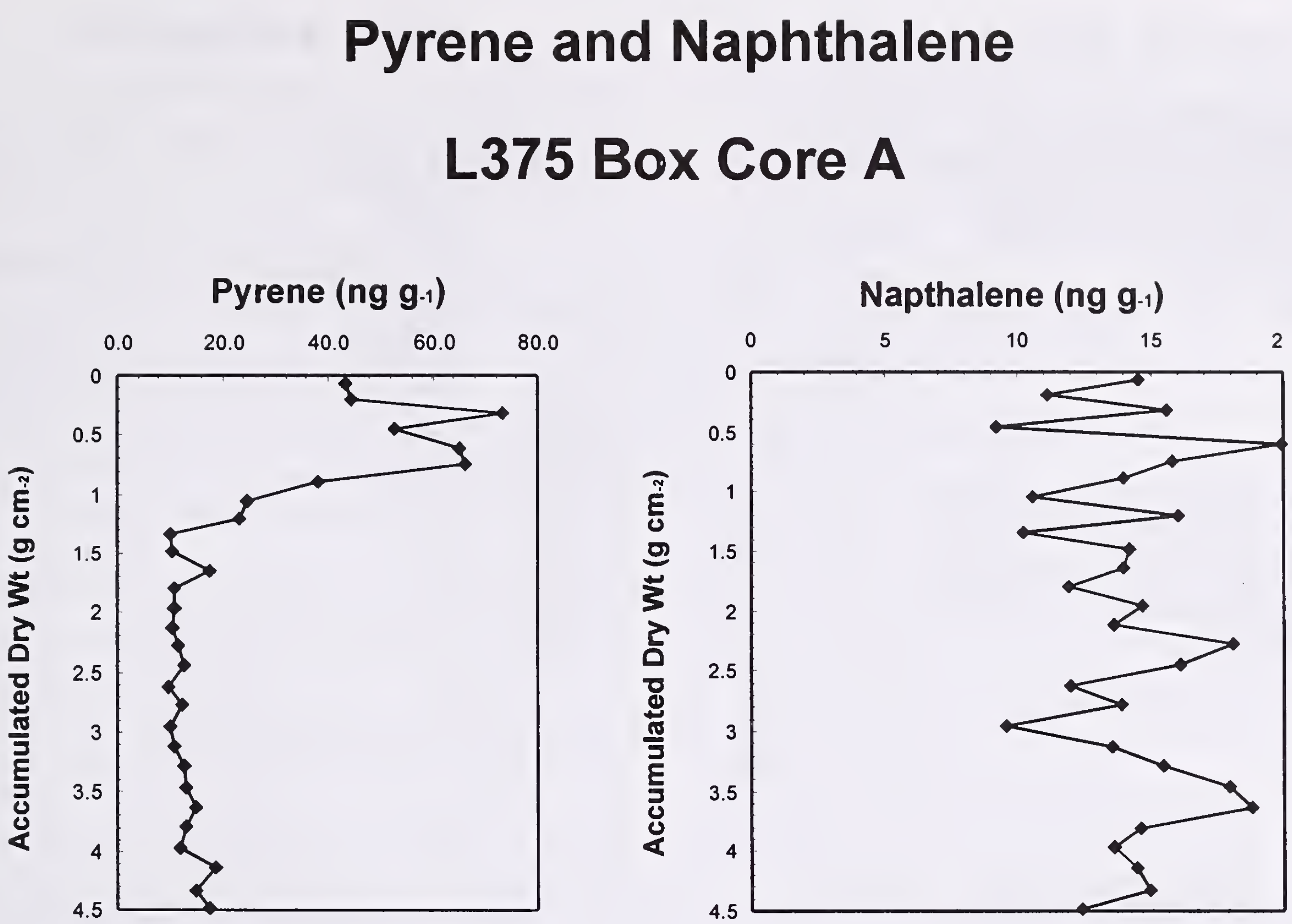


Figure 8. Pyrene and naphthalene profiles from Lake 375

no reason to suspect that the unusual profile from Far Lake is an analytical artifact. Often different PAHs show very different profiles. For example, Figure 8 shows the difference between naphthalene and pyrene in the same core from Lake 375. Naphthalene shows no gradient throughout the depth of the core while pyrene shows the same pattern as that for the total PAHs in Figure 7. We might expect this type of difference in view of the higher water solubility of naphthalene. The erratic pattern shown by the sum of PAHs at Far Lake is not the result of an unusual contribution of any individual component; many of the major components had individual depth profiles similar to that for the sum.

One particular PAH, retene, has shown an unusual profile in sediments of some Yukon lakes (Figure 9). Retene is rich in resins from coniferous trees and has been used as a tracer for wood smoke (Ramdahl 1983). In the Yukon lakes it has a striking elevation around the turn of the century, and we speculate that it may have been deposited then as a result of the "Gold rush".

Chlorinated Hydrocarbons in Dated Sediments

DDT came into commercial use during World War II and so, at the sedimentation rates we usually encounter of 10-15 years per 1-cm slice of sediment, DDT and its derivatives are present only in the top few slices. Figure 9 (adapted from Muir et al., 1995) shows profiles of DDD and other DDT compounds in the upper sediment layers of three lakes. All the lakes show traces of DDD and other DDT compounds in the top layers, consistent with inputs over the past half century. Slices deeper than those shown did not contain DDT or derivatives at measurable concentrations, as would be expected for material laid down in the first half of this century or earlier.

SUMMARY AND CONCLUSIONS

Lake sediment cores, when selected carefully and interpreted critically, offer a means to reconstruct recent (150 year) histories of pollution with a number

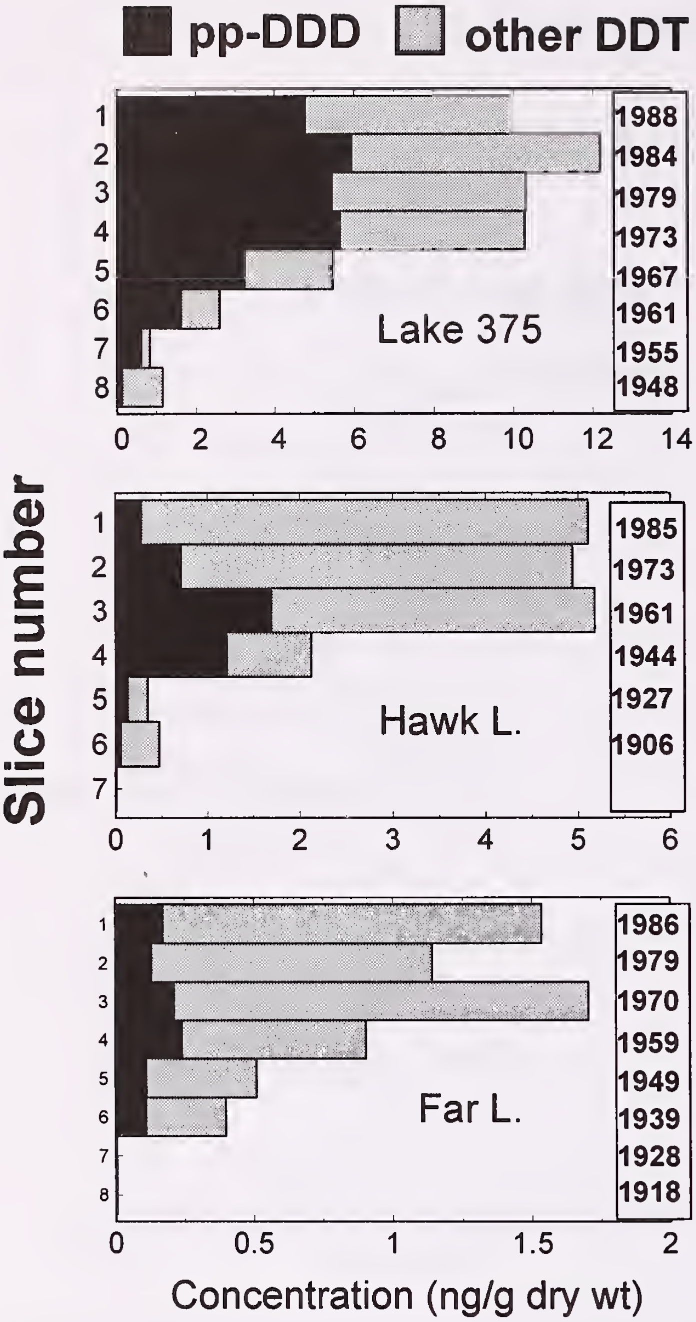
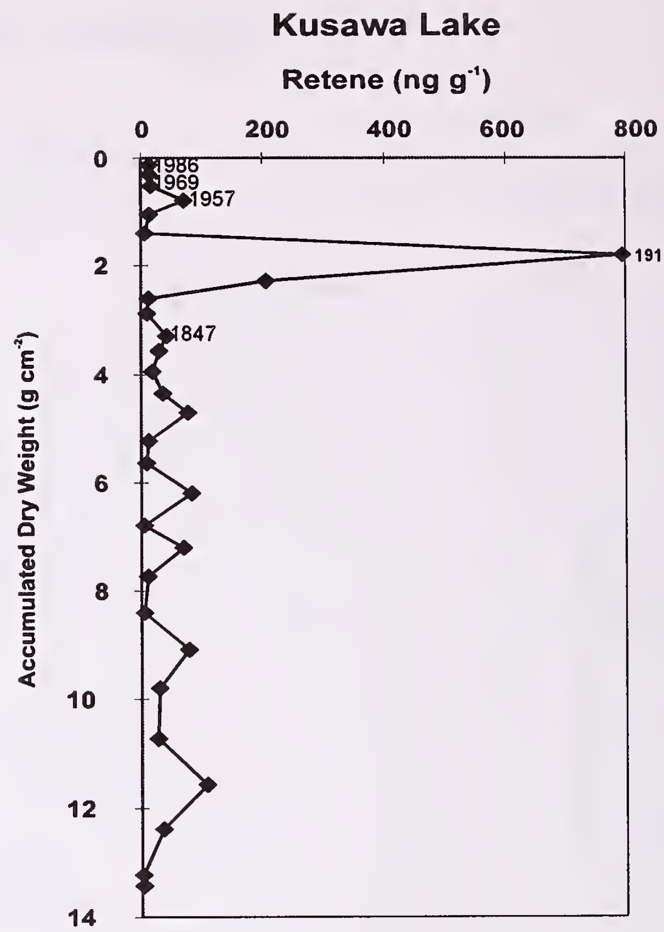


Figure 9. DDD and other DDT derivatives in upper slices of Lake 375, Hawk Lake and Far Lake.

of chemicals including several metals (mercury, cadmium, lead), the heavier polycyclic aromatic hydrocarbons, and a number organochlorine compounds. When combined with radiochemical dating techniques, they can be used to estimate loading rates and changes in those rates over time. In relatively deep cores, extending several hundred years back in time, the techniques offer an estimate of basal geological levels of natural elements and compounds for comparison of recent levels, which can be expected a combination of natural, geological contributions and contributions from pollution. The main requirements are for some knowledge of the size and bathymetry of the lake of interest and its drainage basin. The tendency of the deeper parts of lakes to focus material can



be estimated in several ways and artifacts due to it can be calculated. If longer records are required, dating isotopes other than lead-210 can sometimes be used.

We have extended the approach to marine settings with the collection of several cores from Hudson Bay. Analyses of these cores is incomplete, but three of the four cores analyzed to date for mercury show patterns similar to Far and Hawk Lakes with increases in the upper slices

The approach offers information not readily obtained any other way and its costs are modest. In northern Canada where we have little or no bathymetric information on many small lakes the greatest cost is typically transportation to and from the sites. Usually this requires two trips, a summer trip to make a bathymetric map using GPS/Sonar technology (Gubala, 1994) and a second trip during winter to collect the cores using ice as a stable working platform, although cores can be collected in summer if weather is calm and/or a large boat or ship is available.

ACKNOWLEDGEMENTS

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Aguas Superficiales y Cienegas

Dr. Arturo Chacón Torres[1]

1. INTRODUCCIÓN

Asociados a las actividades humanas se identifican problemas que afectan a los ecosistemas acuáticos incluyendo la extracción del agua con fines de potabilización, irrigación e industria, el vertido de desechos, el azolve, así como la contaminación inorgánica y biológica. Estos procesos aceleran el proceso natural de envejecimiento y extinción de los lagos y ríos, disminuyendo su productividad y uso potencial, con un consecuente deterioro, agotamiento y pérdida de valiosos recursos naturales.

2. EL AGUA EN MÉXICO

La disponibilidad del agua superficial en el territorio mexicano se encuentra determinada por volumenes que escurren a través de corrientes naturales, que a su vez son contenidas en almacenamientos naturales y artificiales incluyendo los lagos, lagunas costeras, presas y ciénegas. Existe además un volumen almacenado en el subsuelo producto de la infiltración y que su profundidad se encuentra determinada por factores geológicos, topográficos y edáficos principalmente.

México posee cerca de 11,593 kilómetros de litoral. En esta longitud costera se encuentran 16,000 km^2 de sistemas estuarinos. De esta superficie el 78%, es decir, 12,500 km^2 corresponden a lagunas costeras. Las lagunas costeras representan el encuentro entre dos masas de agua, dulceacuícola y marina, con diferentes características a los lagos de agua dulce. Las 130 lagunas costeras mexicanas presentan diferente tamaño, régimen hidrológico, biota, hábitats, flujos de energía y problemas específicos.

Por otro lado, la superficie total de agua dulce en la porción continental del país es de 10,000km^2 de los cuales 3,710km^2 corresponden a lagos naturales y 6,290km^2 corresponden a embalses artificales.

Existe un escurrimiento medio anual de 410,000 millones de metros cúbicos. El territorio nacional se encuentra integrado por 37 regiones hidrológicas, ubicadas en tres vertientes principales: Vertiente del Océano Pacífico, Vertiente del Golfo de México y las Vertientes Interiores del Norte. Dentro de las tres grandes vertientes se localizan 320 cuencas hidrológicas las cuales representan el 80% de los escurrimientos.

La captación de la mayor cantidad de precipitación se concentra en lluvias torrenciales durante tres ó cuatro meses del año durante las temporadas de verano y otoño. La precipitación pluvial un promedio de 780mm con un volumen aproximado de 9.53 billones de metros cúbicos distribuída de manera heterogénea y sujeta a grandes variaciones. En el norte del país se registra una precipitación media anual inferior a los 500mm, con un escurrimiento anual de 12,300 millones de metros cúbicos, lo anterior representa el 3% del escurrimiento anual del país en una extensión superficial del 30% del territorio nacional. En cambio, en el sureste del país, la lluvia puede alcanzar una cifra superior a los 2000mm anuales, con un escurrimiento de 205,000 millones de metros cúbicos, en una extensión no mayor del 20% del territorio nacional. En estas condiciones el 49.1% del territorio nacional se considera como seco y muy seco, mientras que el 50.9% se sub-húmedo y húmedo.

Los almacenamientos naturales contienen 14,000 millones de metros cúbicos, mientras que los almacenamientos artificiales presentan una capacidad total de 125,000 millones de metros cúbicos. La cifra anterior significa que el país retiene el 30% del escurrimiento promedio anual. Las presas en México se han construído principalmente para el riego, generación de energía y el control de avenidas.

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En la vertiente occidental o del Pacífico existen aproximadamente 100 ríos, entre los que destacan por su caudal los ríos Balsas, Lerma-Santiago y Verde. La vertiente oriental está constituída por 46 ríos importantes entre los que destacan: Usumacinta, Papaloapan, Grijalva, Coatzacoalcos y Pánuco. La vertiente interior está formada por grandes cuencas cerradas donde los ríos vierten sus aguas en extensas planicies como el Bolsón de Mapimí. El sistema de ríos Nazas-Aguanaval es el más importante.

3. EL USO Y EL DETERIORO DEL AGUA SUPERFICIAL EN MÉXICO

El aprovechamiento actual del agua en México en las cuencas hidrológicas, representa el 92% del valor bruto de la producción industrial del país, en donde a su vez se ubica el 90% de la población mexicana. Dentro de estas cuencas hidrológicas existe un 97% de área sujeta a sistemas de riego que representa el 77% de la superficie del territorio nacional.

La demanda total de agua en el país asciende a 125,500 millones de metros cúbicos. El 77% de la demanda se destina para el riego, el 14% a la industria, el 7% se destina para agua potable y el 2% para la ganadería y la acuacultura.

Las cifras anteriores hacen evidente la gran importancia que tiene el agua como un recurso natural para el desarrollo económico y social de nuestro país. Sin embargo, los conocimientos generados en relación a la estructura y función de los recursos acuáticos mexicanos, así como su potencial productivo no son todavía suficientes. En contraste, el incremento de la población y la creciente demanda del desarollo económico, han magnificado los problemas de sobreexplotación, deterioro y agotamiento de los recursos hidrológicos nacionales.

Existen áreas que manifiestan un déficit hidráulico y que representan un punto de conflicto para un suministro adecuado que permita el desarrollo regional. Ejemplos de estos casos son las ciudades fronterizas de Tijuana, Ensenada, Nogales, Ciudad Juárez, Piedras Negras, Nuevo Laredo Reynosa y Matamoros, mientras que en el centro del país la ciudad de México, Guadalajara y Querétaro existe un incremento paulatino en el deficit del agua. Por otro lado, existen problemas adicionales de conflicto por la calidad del agua en áreas como las de Tampico, Cotzacoalcos y Mérida.

De las 320 cuencas hidrológicas de México el 54% de los niveles totales de contaminación y deterioro ecológico se localizan en 11 cuencas principales que representan las áreas de mayor productividad y desarrollo económico del país. En su orden de magnitud y deterioro estas cuencas incluyen a las del río Pánuco, del Lerma-Santiago, Balsas, Guayalejo (río Pánuco), San Juan (río Bravo), Culiacán, Fuerte, Coahuayana, Blanco (río Papaloapan), Nazas y Conchos.

Un segundo grupo de 43 cuencas hidrológicas contribuyen con un 41% de los niveles totales de contaminación y en donde se localiza el 22% de la población total del país, el 45% superficie total bajo riego y 9% de la producción industrial,

Las 277 cuencas hidrológicas restantes abarcan el 6% de la población y representan un 7% de la producción nacional. Estas cuencas no contribuyen significativamente al volumen total de productividad y desarrollo de México, sin embargo, también se encuentran sujetas a un avanzado proceso de deterioro ambiental.

Los vertidos de contaminantes que se identifican actualmente en los sistemas acuáticos mexicanos son principalmente: 1) las descargas domésticas y municipales, 2) las descargas industriales de la manufactura y proceso, 3) los productos químicos excedentes de la agricultura y la ganadería, 4) las descargas de la industria azucarera y vitivinícola, 5) los desechos y derrames de la actividad petrolera, 6) los desechos de la industria de productos lácteos y alimenticios, 7) las descargas de la industria textil, 8) los desechos de la industria papelera, y en menor cantidad 9) las descargas de las industrias de productos enlatados, la minería, tenería y otros.

La cuenca del río Pánuco ocupa el primer lugar en carga de contaminantes debido principalmente a la influencia de la Ciudad de México y de la Zona Metropolitana. Sus principales fuentes de contaminación se localizan básicamente al principio y en la desembocadura del río Pánuco, mientras que la cuenca del río Lerma-Santiago ocupa el segundo lugar en el rango de contaminanción, sin embargo, ésta presenta un mayor impacto ambiental de la cuenca del río Pánuco ya que sus fuentes de contaminación se encuentran diseminadas a lo largo de su sistema de drenaje. Lo anterior también ha ocasionado un conflicto de intereses en relación al uso del agua, en donde se superponen el

abastecimiento de agua potable, la irrigación, la actividad industrial y la eliminación de desechos. Las descargas de origen doméstico contribuyen con un 42% de la contaminación existente, mientras que la industria química, petrolera, agropecuaria y alimenticia contribuye con 58% de los niveles de contaminación existentes.

En la cuenca del río Balsas la industria azucarera contribuye con el 82% de los niveles de contaminantes mientras que las descargas domésticas aportan el 13%, la industria textil el 2% y la industria química con el 2%. Un análisis en el resto de las cuencas hidrológicas indica en diferentes porcentajes y grados que las descargas domésticas, la actividad industrial y las actividades agropecuarias son las principales fuentes de contaminación y deterioro de los recursos acuáticos del país.

Por otro lado, México no se excluye de los efectos del cambio climático global. Las expectativas del calentamiento del planeta, sugieren un contraste aún mayor entre las vertientes de México, en donde el agua tiende a la escasez tanto en la vertiente del Pacífico como en la Interior del país. Lo anterior, limita la aplicación de modelos hidrológicos confiables que permitan la planificación.

La necesidad de obtener un conocimiento profundo de los recursos acuáticos mexicanos para su conservación y aprovechamiento ha resultado en una consolidación de la limnología nacional. Las últimas décadas se han caracterizado por un fortalecimiento académico y científico de las ciencias acuáticas. Se funda el Instituto de Ciencias del Mar y Limnología de la UNAM, se establece el Centro de Estudios Limnológicos de Chapala, el Instituto de Limnolgía de Chapala, se consolida el Instituto Mexicano de Tecnología del Agua y se funda el Instituto de Investigaciones sobre los Recursos Naturales de Michoacán. Numerosos limnólogos mexicanos se han reunido en diversos encuentros y foros de discusión con el objeto de establecer criterios que permitan una evaluación objetiva y un monitoreo efectivo de los recursos acuáticos mexicanos.

Durante este proceso histórico, los estudios hidrobiológicos identifican claramente, la tendencia de la mayor parte de los lagos, ríos y presas mexicanos como una fuente para el uso múltiple. Por consecuencia, los sistemas acuáticos se encuentran sujetos a una intenso aprovechamiento que en la actualidad los ubica en un proceso acelerado de degradación.

Algunos de los factores que se identifican como causantes del deterioro del recurso dulceacuícola mexicano son:

1) El azolve que procede de las cuencas de escurrimiento y la pérdida de profundidad tanto de los vasos lacustres como de los sistemas fluviales.
2) La extracción intensiva del agua contenida en los acuíferos, vasos lacustres y ríos, para fines agropecuarios e industriales.
3) La contaminación orgánica, ocasionada por el vertido de agua residual de origen municipal, industrial y agrícola, acelerando los procesos de fertilización, envejecimiento y desecación parcial, temporal o total de vasos lacustres.
4) Programas de manejo productivo incompatibles con la realidad social y cultural en las diferentes regiones del país.
5) Estudios de diagnóstico aún insuficientes, aislados y fragmentados.

4. CONCLUSIONES

En México como en la mayor parte de América Latina existe una apremiante necesidad de diseñar estrategias eficientes que permitan rehabilitar las cuencas hidrográficas del país e integrarlas a un sistema de conservación y manejo productivo sustentable. En este sentido, son precisamente las características regionales las que definen los criterios que deben aplicarse en los planes de manejo y uso productivo. Algunas de estas características regionales a considerar son:

a) Fisiografía

La mayor parte de las aguas continentales de México se localiza en relieve montañoso. El terreno cubierto por montañas y sierras representa el 45% de la superficie total del país. Lo anterior indica la existencia de una diversidad altitudinal, geológica, climática y biológica de mayor complejidad que aquella que se presenta en otros paralelos.

b) Asentamientos humanos y diversidad cultural

El aprovechamiento intensivo de los recursos acuáticos mexicanos no solamente es producto del crecimiento de la población, sino también un resultado de los intereses socioeconómicos. En el país confluyen tres grupos sociales bien definidos: a) grupos indígenas con una economía de subsistencia, b) grupos mestizos con un sistema de adopción tecnológica, pequeña propiedad, libre comercio y economía dependiente, y c) grupos industriales y agropecuarios apoyados por fuertes inversiones y consorcios financieros.

c) Uso múltiple del agua

Los sistemas fluviales y vasos lacustres se aprovechan para una diversidad de actividades como el suministro de agua potable, pesquería comercial, recreación, navegación, acuacultura, generación de energía, irrigación, industria, vertido de desechos y enfriamiento de turbinas y reactores. El uso múltiple de las aguas continentales mexicanas requiere por consecuencia, de esquemas integrales de manejo y conservación de recursos.

d) Influencia institucional

La totalidad de las aguas interiores mexicanas se encuentran sujetas a la acción y reglamentación por parte de una diversidad de instituciones. Desde el sector Federal y Estatal hasta del municipal y privado incluyendo a las organizaciones ecologistas y de acción social. Lo anterior, es de considerarse como un privilegio, sin embargo, es necesario establecer con precisión los niveles de competencia y responsabilidad adecuados. Lo anterior, evita la duplicidad de esfuerzos, estimula la integración institucional y permite una mayor eficiencia de recursos humanos, logísticos y financieros.

5. PROPUESTAS

a) Establecimiento de una red nacional de monitoreo organizada y operada por una Sociedad Mexicana de Limnología, integrada por profesionales de las ciencias acuáticas.

b) Establecimiento de criterios regionales de diagnóstico y evaluación contínua de la calidad del agua a través de reuniones, talleres y seminarios realizados por la Sociedad Mexicana de Limnología.

c) Actualización de un inventario nacional de aguas superficiales así como, estableciendo un esquema integral de diagnóstico y evaluación de la calidad del agua.

d) Desarrollo de un plan de ordenamiento territorial identificando unidades ambientales con vocación para la productividad y la conservación de los recursos acuáticos mexicanos.

e) Definir el aprovechamiento de las aguas superficiales con un enfoque hacia el desarrollo sustentable y compatible con la realidad regional.

f) Establecer mecanismos para la evaluación contínua y el monitoreo de los recursos acuáticos, que permitan adecuar prácticas productivas eficientes y establecer esquemas de recuperación de cuencas hidrológicas, bajo tres objetivos principales:
   1) Evitar la sobreexplotación de los recursos
   2) El mantenimiento del ciclo hidrológico regional evitando la contaminación y el deterioro ambiental.
   3) Mantenimiento de la biodiversidad regional.

Estuarios y Zonas Costeras de México Evaluación de los Sistemas de Monitoreo Ambiental

Dr. Virgilio Arenas Fuentes[1]

RESUMEN

En el presente documento se presenta una revision del conocimiento actual de los ecosistemas marinos de la zona costera mexicana; se destaca la importancia y nivel de conocimiento de las lagunas costeras y estuarios. Se concluye que son ecosistemas altamente productivos, de alta compeljidad ecológica producto de la interacción evolutiva de las comunidades continentales acuáticas epicontinetales y terrestres y de las marinas litorales y pelágicas.

Por su alta productividad resultan extremadamente atractivas para actividades de explotación de consecuencias de dificil pronóstico; por su accesibilidad son vulnerables a procesos directos de transfomación y perturbación orientados a incrementar sus rendimientos pesqueros acuaculturales y recreacionales; por su fragilidad y complejidad biogeoquimica responden a perturbaciones indirectas y alóctonas; por lo general resultan ser principal recurso de subsistencia de las comunidades locales que las aprovechan muy artesanalmente.

Se describen los sistemas y redes de monitoreo ambiental existentes en el pais y que son de importancia para el seguimiento de la variabilidad de los parametros ambientales en la zona costera. La descripción se basa en entrevistas realizadas con los responsables de los distintos servicios y esta orientada a evaluar su disponibilidad, utilidad y limitaciones. Se describen el Sistema Mareográfico, la Red hidrometrica, la Red de Calidad del Agua, El sistema Meteorológico Marino, los Servicios de Cartografia e hidrografia y el Programa de Monitoreo de Salud de Moluscos Bivalvos.

Se concluye que los servicios de monitoreo ambiental de la zona costera presentan severas deficiencias que son consecuencia del rezago historico en el desarrollo de la oceanografia regional. Estas condiciones afectan severamente la posibilidad de consolidar planteamientos formales de aprovechamientos que sean congruentes con compromisos de viabilidad ambiental.

Se indican algunos lineamientos generales que podrian ser considerados para dar seguimiento a los resultados de proyectos de modificación y transformación de la zona costera, como regulación pesquera, acuicultura, turismo, etc y se dan recomendaciones especificas para mejorar substancialmente el sistema de monitoreo ambiental en la zona costera.

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Conservacion y Proteccion del Medio Ambiente Marino Litoral
Una Propuesta para Baja California Sur

Carlos H.Lechuga-Devéze[1]

INTRODUCCIÓN

Para la implementación de un plan de manejo para el ambiente marino es necesario contar con el apoyo de personal científico en las ciencias marinas (IOC, 1984). Este conocimiento científico es necesario para la identificación de transformaciones ambientales las cuales, por pescadores o administradores por ejemplo, pueden ser vistas como fluctuaciones normales o bien eventos fortuitos. Los ejemplos sobre este caso son numerosos. El científico es capaz, a través de su experiencia, de coadyuvar sustancialmente en la persuación de proclamar áreas marinas con diferentes *status* de protección, sin embargo, ésta labor requiere de una difícil cooperación social y política.

El problema reside en que aparentemente el medio acuático está revestido de una importacia secundaria (Kechington, 1990), de forma tal que arrojamos en él un sinúmero de desechos, construimos barreras artificiales, transformamos litorales, ganamos terrenos al mar. El costo de este tipo de acciones sin control aparente, puede ser muy elevado. A mediano y largo plazo podremos ser testigos del costo social y económico asociado a la pérdida de importantes procesos ambientales, puesto que se tendrán que ejercer acciones de restauración para poder seguir contando con los recursos que nos ofrece, o bien, sufrir la pérdida total del recurso.

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Los componentes del manejo adecuado de un ambiente marino litoral deben estar dirigidos hacia una definición apropiada de los recursos disponibles, una minimización de los impactos posibles, un control de la contaminación costera. Todo esto puede ser aplicado por el control de los impactos asociados a la pesca, recreación, turismo, puertos, ingeniería litoral, y de todos aquellos materiales que llegan al mar producto de la actividad continental. El reto para conservar o restaurar un ambiente marino sosteniblemente sano consiste en detener la idea de considerar que el mar tiene una ilimitada capacidad de absorción de los impactos generados por la actividad humana. El reto consiste en establecer serios programas de colaboración entre los administradores del mar y los administradores de la economía, que asegure el uso sostenible del medio ambiente marino de acuerdo a los propósitos de desarrollo económico integral del país.

OBJETIVO

La calidad del medio ambiente marino litoral debe contemplar como objetivo la convicción de llevar al cabo acciones que permitan la comunión del medio ambiente marino litoral y el desarrollo económico de los estados, regiones y países que inciden directamente en él.

GRADOS DE APLICACIÓN

La implementación de un objetivo como éste tendrá sus repercusiones en diferentes campos de aplicación:

Preservación de un área en su estado natural.- El desconocimiento completo de los procesos que afectan un área determinada debe ser razón suficiente para considerar dichas zonas en estado de preservación. El uso racional de los recursos necesita de un conocimiento básico de dichas zonas.

Protección de un área crítica para flora y fauna.- El aumento en el conocimiento de nuestros litorales permite identificar zonas particularmente sensibles a la actividad antrópica, así como aquellos recursos o poblaciones naturales que representen un patrimonio ecológico susceptible de ser sujeto a control.

Definición del uso potencial del litoral.- La comprensión de los diversos procesos naturales que inciden sobre determinadas áreas, nos permitirán definir su vocación natural, ya sea turística, para acuacultura, de extracción natural, etc.

Fuente de explotación sostenible de recursos marinos.- La evaluación de los recursos marinos sujetos a explotación permite a su vez determinar cuotas de captura adecuadas que eviten una merma irreversible del recurso. Permite además un control sobre la calidad del litoral costero provocado por la actividad antrópica.

Utilización razonada de diversas formas de explotación.- El avance en el conocimiento de nuestros recursos nos permite la implementación de otros métodos de explotación, como lo sería la acuacultura costera, los cuales permiten un mayor beneficio económico al estado. Implica también la generación de nuevo conocimiento ligado a los potenciales efectos que estos nuevos métodos puedan tener sobre el medio ambiente (p. ej. contaminación ligada a la acuacultura), y preservar así el recurso en una producción sotenible

Máximo beneficio económico, máximo uso sustentable.- El dominio completo de los recursos naturales, de los diversos métodos para incremento de su biomasa, de la gestión concertada con todas las actividades económicas marinas o terrestres, permitirán obtener este alto grado de utilización razonada.

LITORAL DE BAJA CALIFORNIA

La península de Baja California (Fig. 1) tiene una gran vocación hacia la explotación de sus recursos marinos. Los dos estados que la conforman poseenla mayor extensión litoral mexicana, contando además con una apertura natural tanto al Océano Pacífico como al Golfo de California, ambos con una alta productividad y diversidad de especies tanto comerciales como potenciales.

El futuro económico de aja California descansa más sobre sus recursos marinos y particularmente en una gran vocación acuacultural. El limitado recurso del agua no permite un desarrollo agropecuario o industrial. Por tales razones, la península de Baja California quizá tenga el único litoral mexicano con una mínima o nula influencia de actividad antrópica, lo que la hace idónea para aplicar con éxito los planes de manejo adecuado de su litoral. Puntos críticos existen en la desembocadura del río Colorado, del lado del Golfo de California, o en la frontera con los Estados Unidos, en la costa del Pacífico. Pero, es evidente que aparte de estas áreas, el resto de nuestro litoral se encuentra en estado casi natural. Particularmente, el CIBNor ha desarrollado diversas investigaciones en Baja California Sur que nos permiten conocer las influencias naturales a las que está sometido.

Las investigaciones de nuestro litoral que pueden ser importantes para el mantenimiento de cierta calidad ambiental, han tenido como eje la explotación de moluscos bivalvos y las repentinas mortandades masivas o puntuales que han ocurrido en diversas lagunas como Ojo de Liebre, San Ignacio, Magdalena o Bahía Concepción. De esta forma se vislumbran problemas altamente asociados a fenómenos naturales como la causa. Por ejemplo, en Bahía Concepción, aparentemente una alta productividad que ocurre en los meses de invierno y una batimetría particular permite una acumulación importante de materia orgánica en su cuenca central. El calentamiento atmosférico y una bébil energía de circulación de agua provoca a su vez que se forme un fuerte gradiente térmico en la columna de agua que aisla el estrato superficial del estrato profundo (Fig. 2). En este estrato profundo ocurre entonces una intensa oxidación de la materia orgánica acumulada que abate el oxígeno disuelto, creando para fines de verano una extensa capa hipóxica e inclusive anóxica; de esta forma, cuando por movimientos semejantes a olas internas esta capa anóxica invade las áreas donde se encuentran los bancos naturales o zonas acuaculturales de almeja, las condiciones son propicias para que ocurran las mortandades súbitas de este molusco (Lechuga-Devéze, et al., en revisión).

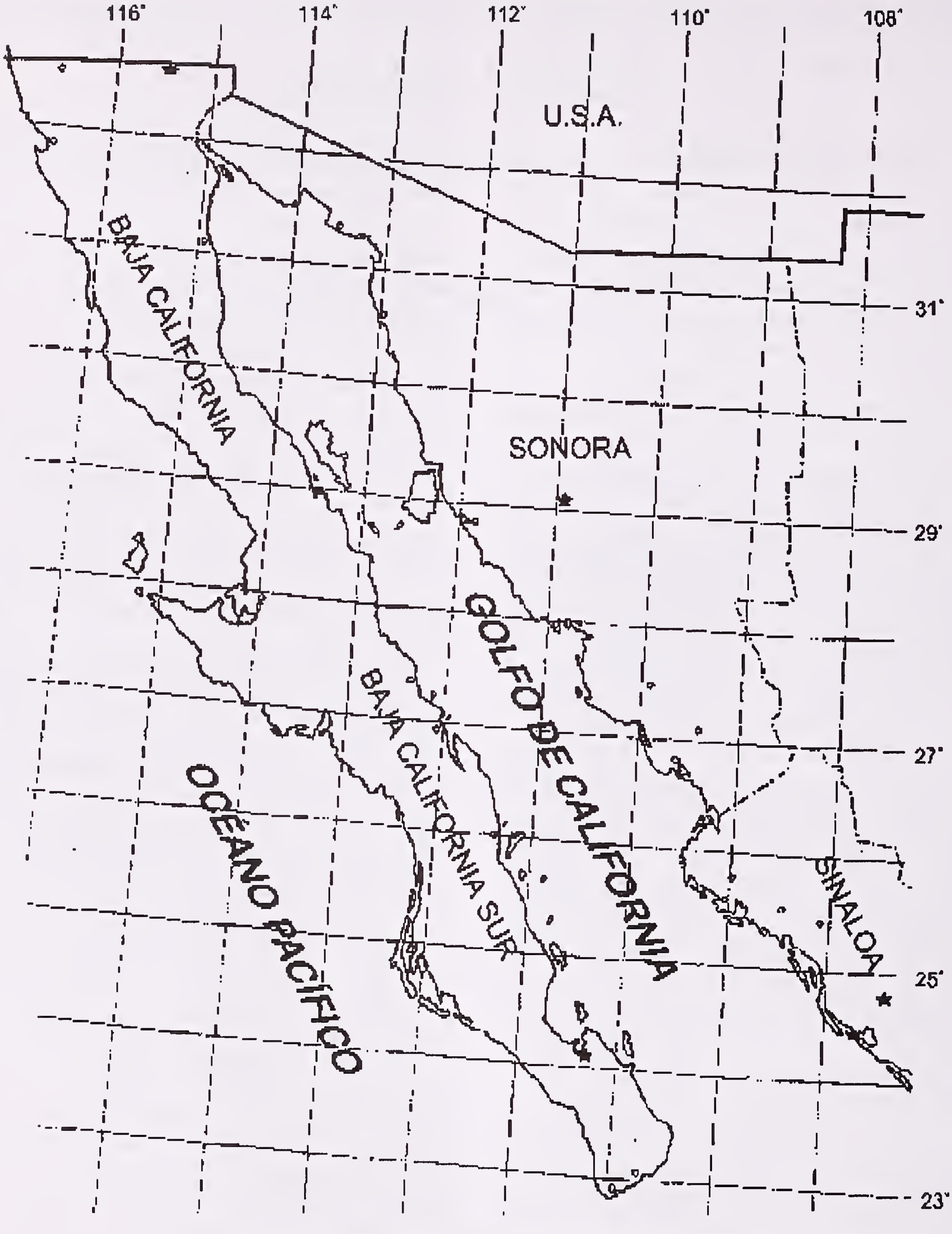

Figura 1. Península de Baja California y mares adyacentes.

Este fenómeno tiene consecuencias no solo en la actividad económica de la región, sino en los procesos naturales que ocurren en la Bahía. La intensa oxidación de la materia orgánica provoca una emisión importante de elementos iónicos, nutrientes elementales para la actividad fotosintética. Luego, esta riqueza en nutrientes minerales parece ser la causa de la generación de importantes biomasas fitoplanctónicas justo por arriba de la termoclina (Reyes Salinas, 1994), pero también de una extraordinaria generación de otros organismos unicelulares, posiblemente quimiotróficos, que se desarrollan justo por debajo de ella (Lechuga-Devéze, 1994). El papel de estos organismos nos es completamente desconocido.

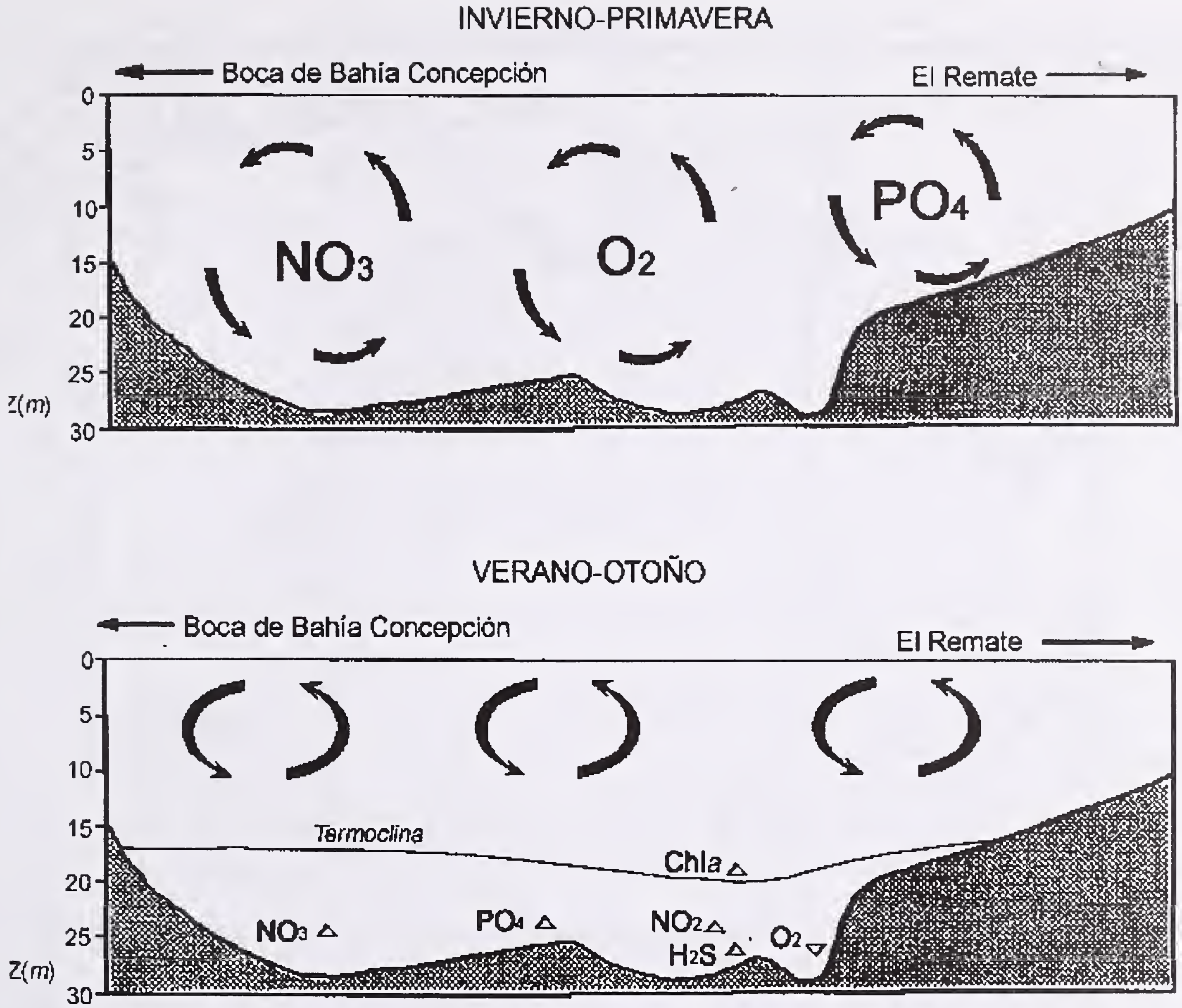

Figura 2. Representación esquemática hipotética de dos períodos anuales, homogenización (invierno) y estratificación (verano) cuyo dinamismo puede ser una de las causas de mortandades de moluscos bivalvos.

Un segundo fenómeno, asociado también a procesos naturales, es la detección de diferentes biotoxinas provenientes de dinoflagelados tóxicos. En efecto, frente a la Bahía Magdalena, en las rocas Alijos (Fig. 3), hemos documentado la aparición de casos de ciguatera por la ingestión de cabrillas (Lechuga-Devéze y Sierra-Beltrán, 1995); los organismos causantes no han sido identificados sino que por sus efectos. Por otro lado, en Bahía Concepción, se han podido identificar dinoflagelados potencialmente tóxicos asociados a diferentes tipos de toxinas presentes en moluscos bivalvos (Fig. 4) como la toxina paralítica y la toxina diarreica (Morquecho-Escamilla, 1996; Lechuga-Devéze y Morquecho-Escamilla, aceptado).

Los procesos que han provocado la aparición de estos tipos de toxinas, se asocian más a eventos naturales. En otras partes del mundo, las mareas rojas tóxicas son frecuentemente asociadas al incremento en la actividad antrópica, a la "eutroficación cultural". Sin embargo, en Baja California Sur, tanto las rocas alijos como la Bahía Concepción, no están sujetas a esta condición.

Es necesario incrementar nuestros esfuerzos para desarrollar programas de monitoreo que puedan identificar los cambios naturales y/o antrópicos capaces de modificar ostensiblemente la calidad de nuestras aguas, y poder efectuar así, una gestión correcta de nuestros recursos para evitar tanto efectos negativos sobre la economía como sobre la salud humana.

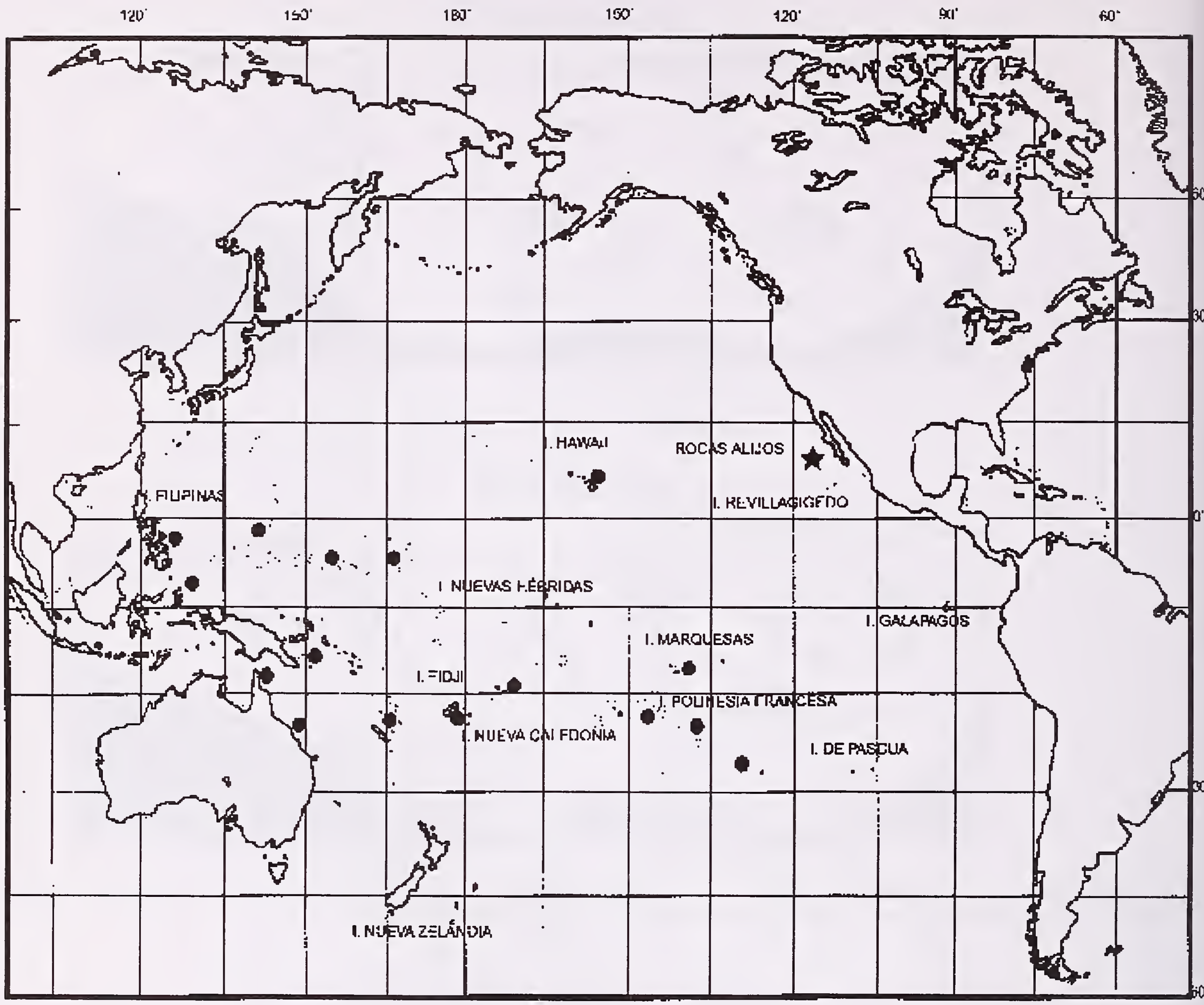

Figura 3. Mapa que muestra los sitios de ocurrencia de Ciguatera incluyendo el evento reportado para Rocas Alijos, Baja California Sur.

ACCIONES

El respaldo científico que nos permita tomar acciones inmediatas ante un evidente deterioro ecológico del litoral, deberá consistir en un acopio de información existente, ordenada en tiempo y espacio, interinstitucional, que resultaría en la creación de la *Red de Observación de la Calidad del Ambiente Litoral (ROCAL)*, con los siguientes objetivos:

- Análisis de la información existente
- Diagnóstico actual
- Medidas de control y/o recuperación
- Monitoreo de variables indicadoras
- Acciones inmediatas ante posible alteración ambiental

Diversas acciones se llevan al cabo. En Baja California Sur se ha implementado el Comité de Contingencias Ambientales, interinstitucional, que se reúne ante una contingencia como el caso de mareas rojas. Por otro lado, nuestra participación en el Programa Mexicano de Sanidad de Moluscos Bivalvos, comité Baja California Sur, nos permitirá

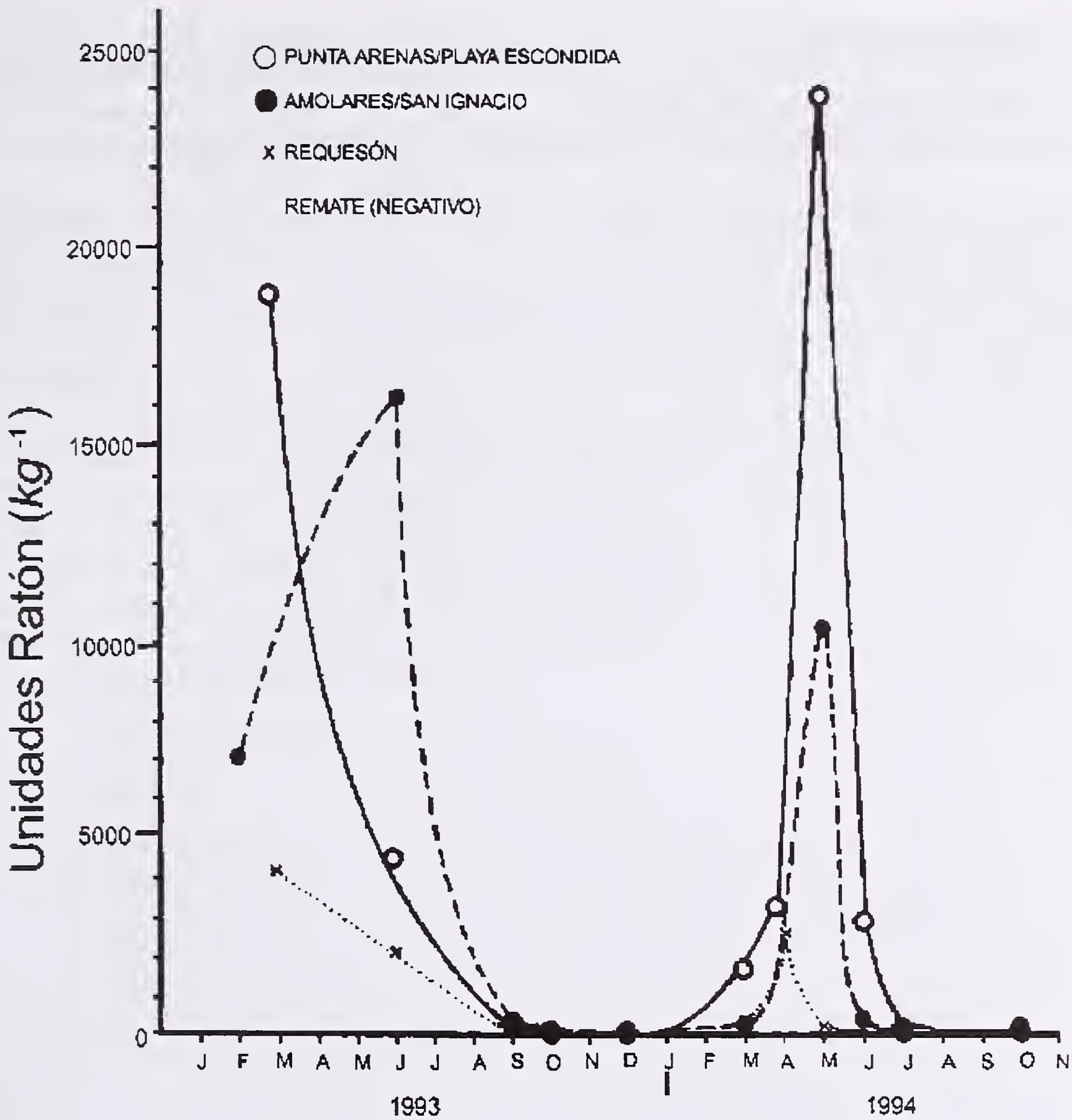

Figura 4. Detección de toxinas paralíticas en la almeja *Argopecten circularis*, para diferentes zonas dentro de la Bahía Concepción.

efectuar a mediano plazo un diagnóstico ambiental del litoral del estado, con particular énfasis a su proyección acuacultural.

La creación de un organismo único, interinstitucional, que lleve a cabo toda esta labor, redundará en una conjunción de esfuerzos y optimizará recursos disponibles. Las diversas instituciones que participan en la generación de información sobre este litoral costero, necesitan promover esta ordenación de esfuerzos para un bien común: el racional manejo y explotación sostenible de los recursos marinos de un área mexicana esencialmente en estado natural. Debemos actuar con medidas de prevención, no de remediación.

AGRADECIMIENTOS

El trabajo de investigación realizado en los litorales del estado de Baja California Sur, son resultado de una estrecha colaboración en el Grupo de Ecofisiología Marina del CIBNor. Por ello, agradezco la participación en la generación de este conocimiento a Ma. Lourdes Morquecho Escamilla, José Reyes Hernández Alfonso, Amada Reyes Salinas, Ibán Murillo Murillo y Francisco Hernández Sandoval. Agradezco también a Arturo Sierra Beltrán por su participación en algunos análisis sobre biotoxinas en moluscos. A Renato Mendoza Salgado, por su ayuda en la elaboración de este documento.

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Research and Development Needs in Monitoring Agroecosystems in Canada

C. A. Scott Smith[1]

Abstract.—The research effort to design and monitor the health of agroecosystems in Canada has evolved over the last 3 to 4 years. Within Agriculture Canada, data used in making assessments are collected through field monitoring programs and obtained from census statistics, remote sensing instruments, crop insurance records, soil surveys and provincial land use surveys. Our primary objective is to try to measure the long term sustainability of various farming systems. Risk assessment is one method useful for soil and water degradation. Alternatively, a balance is calculated, as in the case of assessing farm input use efficiency, greenhouse gas dynamics and nutrient budgets. In the case of agroecosystem biodiversity, the scientific sampling protocols required to make these assessments are still under development. Many physical process models can be extremely valuable in making sustainability assessments. However, most are designed for use on plot or site scales. A major challenge is to extrapolate site modelling and monitoring results to broad regional landscapes (ecoregions) for national and international interpretation and presentation.

INTRODUCTION

This paper briefly reviews some of the major issues that researchers face in the development of agri-environmental indicators based on my experience working with Agriculture and Agri-Food Canada.

Most of the issues that we face are generic in nature, they could apply as well to any other resource sector. Universal problems relate to availability of resources, expertise and data. Technical problems stem from our lack of understanding of the ecosystem processes as they occur in agricultural ecosystems and how we can aggregate and generalize information about these processes at very broad scales. The general process we followed to define a set of indicators and a general overview of the project are presented in the paper by McRae et al (this volume). My comments relate to the research and development constraints and issues that we have experienced to date.

DEFINITIONS AND TYPES OF ASSESSMENTS

Definitions

Researchers have debated extensively the definitions of many of the terms used in ecological monitoring and assessment activities. Ultimately the definition can affect the direction and scope of the research effort. From the standpoint of agriculture, the

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concept of sustainability remains elusive. Agricultural sustainability is location and time specific, universal approaches to measure it are not applicable even though there are universal principles that can be used to define it (Dumanski and Pieri, 1995). The work on agricultural ecosystems in Canada follows the general definition of sustainability of the Bruntland Commission (WCED, 1987) wherein sustainability is defined as meeting the needs of the present, without compromising the ability of future generations to meet their own needs.

The definition of agri-environmental indicator adopted by Agriculture and Agri-Food Canada is:

> "A measure of change in the state of environmental resources used or affected by agriculture, or in farming activities which affect the state of such resource, preferably in relation to standard, value, objective or goal" (McRae et al. this volume).

As opposed to monitoring, which is the collection of raw data, indicators are statistics or measures that relate to a condition, change of quality, or change in state of something valued. These statistics act as indicators if they have some added significance and are tied to some specific application. If the number of indicators is reduce by aggregating them according to some formula, then these may be called indices. (Dumanski and Pieri, 1995).

In reality not all indicators refer to some quantitative standard but should relate to some societal value or objective. While the research community has, for the most part, defined the terms we use and the scope of our research and development activities, society's broad environmental objectives (standards) are often not established. When this is the case, making interpretations about the results of these assessments may be problematic.

Criteria for Selecting Indicators

From the standpoint of scientific rigour, the statistics generated to act as indicators must meet fundamental requirements in order to be credible. The need for an indicator by government policy makers often challanges the ability of the research community to deliver something credible in a timely fashion.

In addition to the need for all indicators to be relevant to policy and environmental issues, Moon and Selby (1995) outlined the following analytical criteria for selecting an indicator:

- availability of data for it's calculation,
- scientific credibility (as measured by statistical defensibility and/or theoretical consistency) of that calculation,
- the ability of the indicator to reflect diversity and status at multiply scales,
- clarity in it's interpretation of change or status, and
- potential comparability to some international standard or method of calculation, if such exists.

The above represents a major challenge to the research community and begs the question "What are the trade-offs that we are willing to make in order to produce a less than perfect indicator, when the alternative is no indicator at all?". The issues of selection criteria underlie almost all of the broader issues of indicator research and development discussed in this paper.

Agri-Environmental Indicators and Types of Assessments

Agri-environmental indicators relating to land, water, air and biodiversity under development are discussed in detail by McRae et al., (this volume). Table 1 lists these indicators and the types of assessments used for each. No one form of assessment works for all indicators. There are three general types of assessment approaches used by our research team: risk, balance and measured change. These may be characterized in the following way:

Risk: assessment of a resource condition measured as a probability of some negative change. This is the approach used in soil degradation assessment where certain soil properties coupled with specific land management actions generate some level of probability of degradation. It requires an understanding of the processes producing degradation but does not require any direct, absolute measurement of degradation. It may or may not involve the use of process models but does require validation of interaction assumptions against actual field responses. This approach is well suited to regional, national and international assessments.

Balance: assessment of a resource condition measured as a balance between management input versus output of some material, energy or chemical

Table 1. List of agro-ecological indicators and the type of assessment used with each.

Environmental Issue	Performance Indicator	Type of Assessment
Land Resources	Soil Degradation	Risk
	Soil Cover and Mgmt	Measured change
	Farm Input Mgmt	Measured change
	Input Efficiency	Balance
Water Resources	Water Contamination	
	- pesticides	Risk
	- nutrients	Balance
Atmospheric Resources	Greenhouse Gases (CO_2, CH_4, N_20)	Balance
Biodiversity	Habitat Availability	Measured change
	SpeciesDiversity/Abundance	Measure change

compound. This is the approach used in assessing nutrient loading, farm input management efficiency, and gas exchanges. The calculations tend to be data intensive, requiring comprehensive information about both inputs and outputs or fluxes. Generally balances are expressed as some sort of index but where appropriate can be expressed in absolute terms (i.e. agriculture has a net contribution to atmospheric CO_2 of 18 Mt $ha^{-1}y^{-1}$). While balance calculations are generally easiest at site levels, the major research challenge is to determine what the appropriate balance should be and extend these calculations credibly over national scales.

Measured change: the direct measurement of change over time without major data manipulation. In Canada, the use of Census of Agriculture data allows time trends to be developed in terms of the adoption of various soil conservation practices, cropping systems and land use. This technique may also employ remotely sensed data or any form of data collected in a repetitive manner over time. Ecosystem monitoring for species abundance/diversity, soil benchmark sampling, and spatial analyses of changes in wildlife habitat are examples of measured change assessment. Measured change is retrospective. Extrapolation may generate projected future trends. The major research challenge is to determine ecosystem sampling protocols (such as biodiversity monitoring) or which form of census data to process.

The choice of assessment approach is dependant on data and process model availability, existing monitoring networks, expertise and the nature and intent of the indicator itself.

RESEARCH AND DEVELOPMENT ISSUES

The following sections describe in more detail some of the issues that Canadian researchers face in the development of agri-environmental indicators.

Understanding Ecosystem Processes

Indicator development is dependant on our understanding of the ecosystem processes involved. While we understand the basic processes of soil erosion, and are constrained mainly by available data, the same may not be the case with the process dynamics of soil faunal populations. Yet biodiversity of agroecosystems is considered an important measure of ecosystem health and therefore defines clearly research needs in this realm. While the pathways of the hydrologic cycle are reasonably well understood, good quantitative estimates of the magnitude of flows in specific components of agroecosystems under varying regional climatic conditions are often difficult to make. The result is that national evaluations of water contamination are limited to simple risk assessments. Similarly, until we understand and can accurately model the dynamics of nitrous oxide in agroecosystems, we cannot determine the total greenhouse gas contributions to the atmosphere from agriculture. The scientific community cannot produce credible statements about ecosystem health if it does not understand the functions, transformations and interrelationships that occur within it. We usually operate with partial knowledge of the system and this requires that we validate our indicators , modify our computations and revalidate continuously.

Expertise and Data Availability

Expertise and data availability define the limits of what can be done. Within Agriculture and Agri-Food Canada we determined that soil compaction was an important component of our soil degradation assessment. Indicator development has yet to proceed on this issue because there was not a soil physicist to develop the assessment. Therefore partnerships between government, university and private research organizations become an important part of any large research effort.

The issue of data availability involves both the quantity and the quality of data.Any approach to developing an indicator, be it process model, expert system or simple measurement of adoption of soil conservation practises, requires access to some form of data. The data available must be of sufficient quality to support the required reliability of the indicator value and the variability of the data should be such that the variability of the calculated indicator values determined from the data is acceptable (Moon and Selby, 1995). Are estimated values for ecosystem attributes acceptable, are single values, are means and standard deviation necessary? When making national assessments are the data from across the country collected/determined in a consistent manner and how reliable are they? Temporal assessments are often hampered by changing sampling or analytical methods over time. Inconsistent, unreliable data generate inconsistent unreliable indicators. With the proliferation of new resource databases there is a fundamental need to insure we properly document data properties so that their quality and usefulness can be determined.

Integrating Socio-Economic Data with Biophysical Data

There is an accepted international movement toward monitoring and reporting on the environment according to ecological(ecozones, ecoregions, etc) rather than political spatial units. In order to undertake certain assessments itis necessary to effectively link the required socio-economic data to these ecological units. Traditionally, most of these data have been organized along political boundaries - county, state, province, country, etc. This integration is more complex than undertaking simple GIS "overlay and extract" procedures. Data must be allocated, a time consuming process of intersection and examination.

In Canada, agricultural census data are spatially organized through various levels of census units that generally reflect population density and political boundaries. Dumanski et al. (1994) were able to summarize the status of land management practices on agricultural land in Canada by province. However, when census information is overlain with 1:1,000,000 scale soil map polygons, information about management systems can be matched to soil type - the key step in making soil degradation risk assessments. Unsupervised digital "overlay and extract" resulted in agricultural data being assigned to soil polygons where no agriculture was possible (rocklands, wetlands, escarpments, etc) or where crop production known to occur only on well drained soils was assigned to polygons dominated by poorly drained soil. Because wildlife data are stored according to game management zones, forest inventory data by forest management units, and groundwater data by county, we face this issue in all sectors. Assigning site specific data in order to characterize spatial units can also be a challenge. We are faced with a long process of first transforming historical data sets, and in the future, compiling monitored data along common ecological frameworks for reporting purposes.

Management/Distribution of Disparate Datasets

Within the relatively small circle of agri-environmental indicator researchers in Canada, where necessary, we should all be accessing the same datasets. When older data are transformed, (as is the case with our historical census data), new satellite datasets purchased, or specific model input formats completed, these should be maintained and made readily accessible to all. Unfortunately, duplication of these activities within the research community has occurred.

Keeping digital information organized in accessible form is best left to data management professionals. Every research organization needs them, to make decisions about software environments, to assist with data modelling, to coordinate the formatting of data for the plethora of process models that we use and

finally, to oversee data quality control. As we become more sophisticated in our analytical techniques, such as the development of the agro-ecological economic modelling system constructed around the Canadian Regional Agriculture Model (Figure 1) (Agriculture Canada 1995), data management, co-ordination and distribution become increasingly critical. We must not underestimate the resources necessary to enable the effective use of information technology in our assessments.

To Model or Not to Model

There is no shortage of models to choose from relating to many of the major agroecosystem functions. Moon and Selby (1995) reviewed 10 available models with application nutrient contamination of groundwater from agriculture alone.

The first issue is the required validation of any given model to Canadian climate-landscape conditions. Many of the agricultural models available have been developed in the United States. Biogeochemical transformation coefficients, crop-weather growth responses, even the effects of seasonal frost, will necessitate model modifications in order to more accurately emulate local conditions. Indicator development is supported by a network of 26 soil benchmark sites distributed across Canada representing major farming systems (Wang et al. 1995). Intensive monitoring at these sites allows validation of indicator modelling results and their extrapolation over regional landscapes.

A second issue relates to scale. There are a number of excellent models that are of use to the developers of agri-environmental indicators. One such model is CENTURY which used to estimate the rate of change of carbon in soil. This is a site specific computer simulation of the dynamics of soil organic matter. The erosion prediction impact calculator (EPIC) was designed to evaluate long term, soil degradation impacts on site crop productivity. Quantitative models of chemical fate in soil (LEACHM, PRZM)

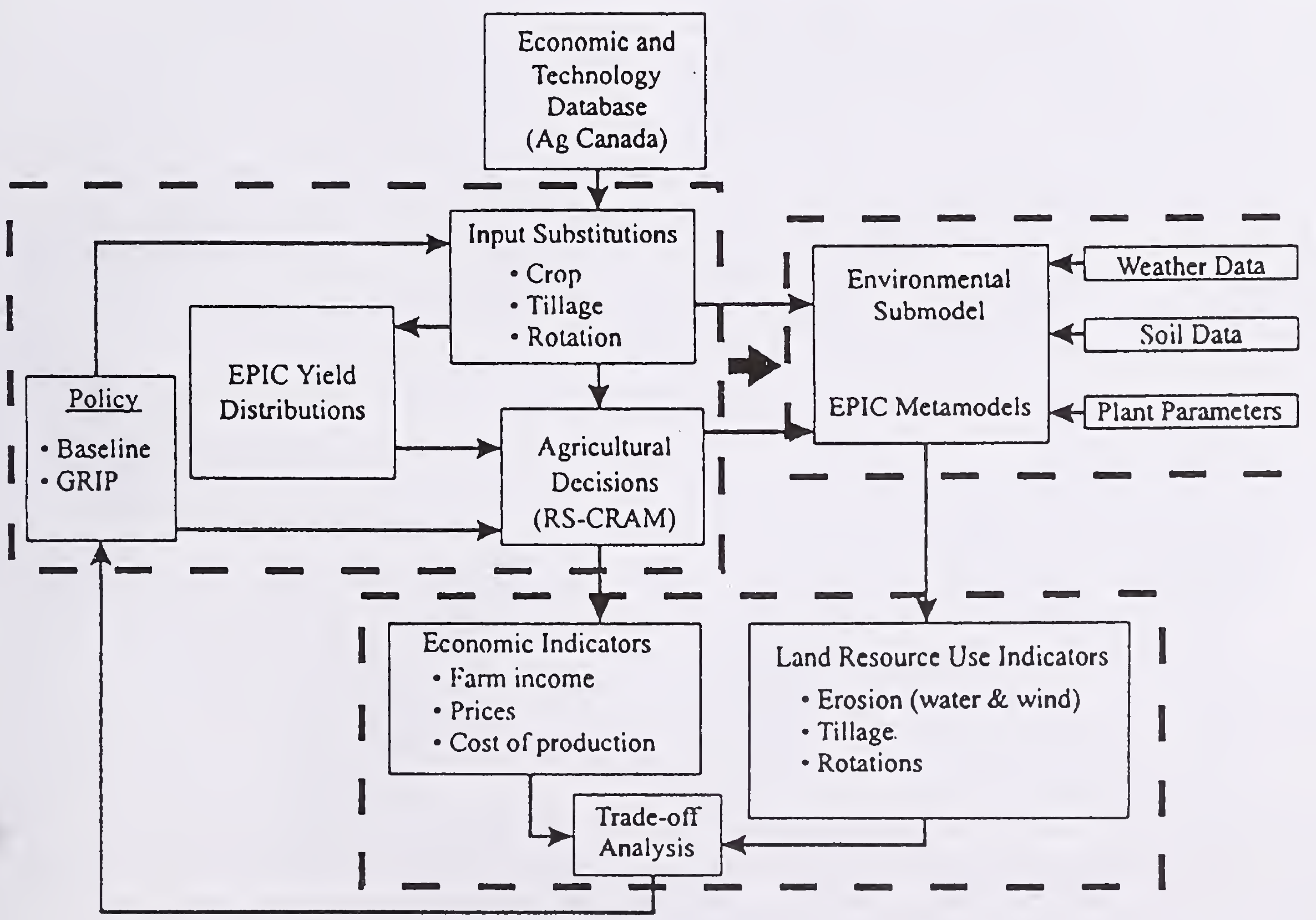

Figure 1. The agro-ecological economic modelling system linking the Erosion Productivity Impact Calculator (EPIC)and the Resource-Sensitive Canadian Regional Agricultural Model (RS-CRAM). Data management becomes increasingly important as the number of disparate datasets that must be integrated into the system increases.

are available to estimate the amount of a pesticide partitioned in soil water (MacDonald and Spaling, 1995). As these models are generally site-specific and applicable only at the most detailed spatial levels, a tremendous amount of development is require to modify these to operate with regional functionality and to be less data intensive. An example of this was the use by Smith et al, (1995) of CENTURY to produce national evaluation of soil carbon loss using generalized soil information and extrapolating results over areas of similar soil great group. The success of this approach awaits validation. On-going work of this nature is one of the research directions of the National Soil Data Base group of Agriculture and Agri-Food Canada.

Process based models are not always necessary nor appropriate for all indicator development. They can however play a role in helping researchers understand particular components and functions of ecosystems. In summary, the use of a model to make predictions in a context for which it has not been validated in an appropriate way constitutes an abuse, and can be particularly serious when government policy is involved (Addiscott et al. 1991).

Temporal and Spatial Considerations

To assist in the monitoring, modelling and extension of results, Canada has developed a hierarchical system of ecological units ranging in scale from 1:1,000,000 to 1:7,500,000 (Ecological Stratification Working Group, 1995). This cartographic system incorporates nested polygons within which information can be aggregated and reported at ecodistrict, ecoregion or ecozone levels (Figure 2). Examples of the use of this framework are given in McRae et al. (this volume). While the correlations necessary to prepare the national coverages of these ecological

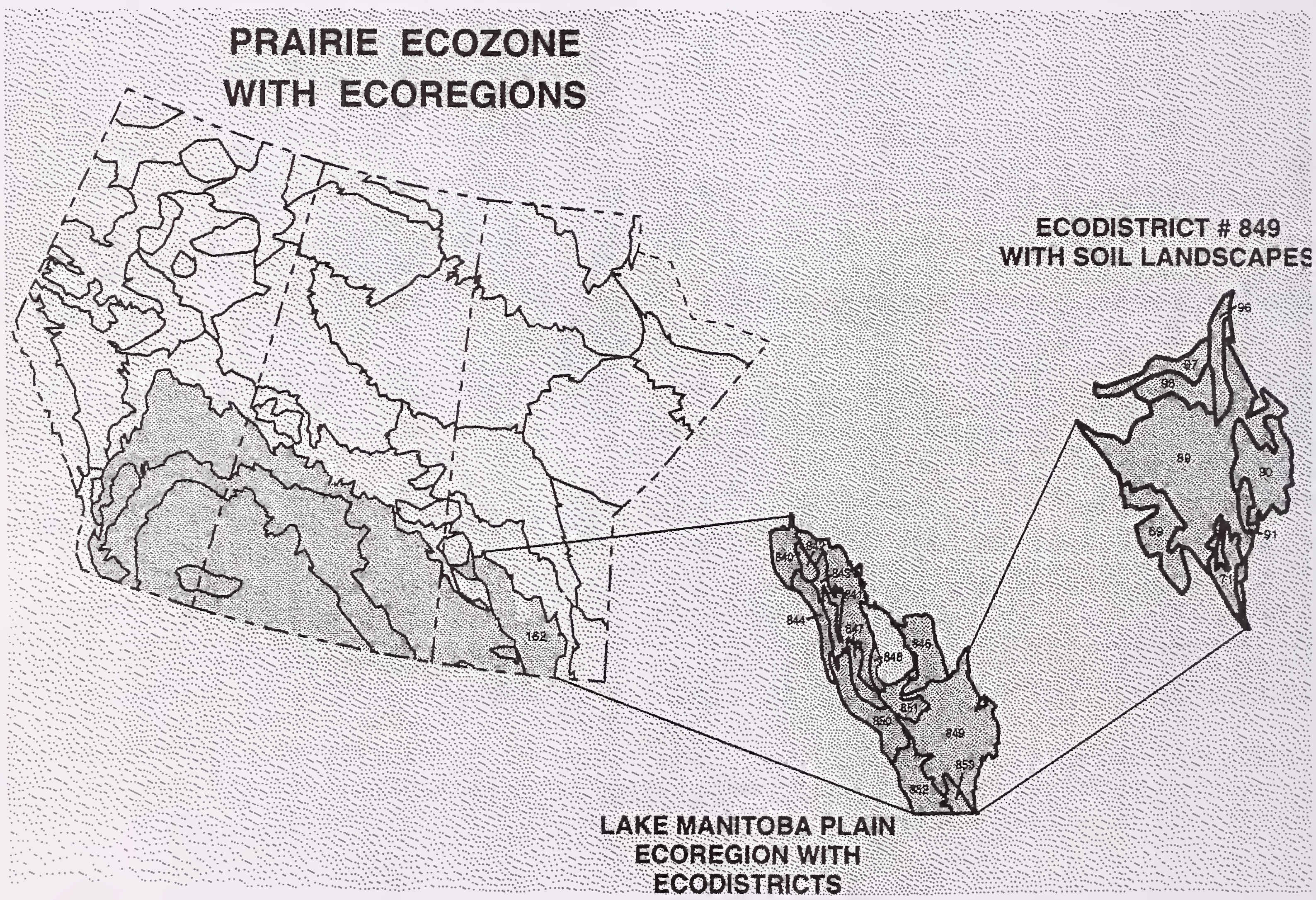

Figure 2. Ecological units are "nested" within the hierarchical structure in the national ecological framework. Monitoring and assessment are linked to the soil landscape polygon and results may be compiled or reported at any appropriate level in the system through aggradation or extrapolation.

map units are complete, linking and compiling resource data to this common cartographic base remains an ongoing task as discussed previously.

We develop an environmental indicator to assess where we have come from, where we are now and project future trends based on certain assumptions. Prospective indicators are model based, retrospective indicators can be simple compilations of data. Until model development and validation have moved farther ahead, future projections, with only a few exceptions, will be limited to extrapolating trend lines from past measured values.

Interpretation and Communication of Results

Interpretation of indicators can vary depending on the scale used to report the results. The aggregated result may obscure the local reality. For example, we may report that a new agriculture support policy will result in no net increase in soil erosion in the Prairie ecozone of western Canada. Yet within this ecozone, local farming systems will change with the result that significant increases (or decreases) in soil degradation will occur at the ecodistrict level. We may report that the national nutrient balance for Canadian agriculture is neutral, and this would be interpreted as good. The reality may be that ecoregions within western Canada have negative balances (indicating soil nutrient reserve mining) and in eastern Canada positive balances (indicating ecosystem contamination).

It is sometimes difficult to establish the benchmark or threshold value above or below which an interpretation can be made. Where environmental objectives are not defined, interpreting assessment results as "good or bad" can be problematic. One might ask the question whether 5 T $ha^{-1}y^{-1}$ loss of soil C is acceptable in the Great Plains? When assessing ground water contamination from fertilizers, do we measure our results against standards for drinking water, irrigation water, national standards or international standards?

Finally, in Canada a series of "National Environmental Indicator" bulletins and technical supplements presents technical, peer reviewed, information to the general public in a simplified format (see Environment Canada (1995) as an example). Ultimately it is the general public and government policy makers who are the consumers of our research and development products. There is an increasing demand for competent technical writers to portray and communicate this information clearly, accurately and in an unbiased manner to the non-specialist.

CONCLUSIONS

The requirement for agri-environmental indicators by government policy makers, international trade agreements, industry producers and the general public provides the research community with an opportunity and mandate to further basic research into agricultural ecosystems, monitoring systems and physical process models. We can utilize both new and old data to make interpretations in a context never before realized. While it is important to respond quickly to this demand, we must be sure that certain scientific fundamental be followed in ensure the credibility of our results and interpretations.

Most of the research and development issues relate to the availability of scientific expertise, high-quality relevant data, analytical tools and functional spatial frameworks. While our initial developments are limited by these constraints, they also clearly point the way for future research.

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The EMAP - Agricultural Lands Experience: Guideposts for Future Travelers

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Abstract.—The Agricultural Lands Resource Group has been a part of EMAP, a research program that would have led to nationwide monitoring of all the major ecological resources in the United States. EMAP-Agricultural Lands is one of several complementary efforts to monitor US agricultural resources, among them USDA-NRCS's National Resource Inventory, USDA Area Studies, and USDA-NASS's farm pesticide use surveys. It is an interagency effort, started in 1989, that operates in the context of both national environmental policy and the sustainable agriculture movement. We are limiting ourselves to monitoring the biophysical aspects of condition and sustainability of agricultural lands, while agreeing that economic and social aspects are also important. Agricultural lands are continually and intensively managed, and so cannot be compared to pristine systems. Thus, we judge their condition on how well they are satisfying societal values placed on them: productivity; quality of air, water, and soil; and biological diversity. Our indicators are tied to these values as well as to ecological processes in the agroecosystem. We have been working on indicators such as: yields in comparison to historical averages and in relation to nitrogen applications; the quality of soil for plant growth and for environmental buffering of chemicals; chemical and biological health of farm ponds; ozone biomonitoring using clover; spatial and temporal crop diversity; nematode trophic structure and diversity; ant diversity; and suitability of windbreaks as breeding habitat for birds. Methods for tying indicators into coherent overall assessments remain elusive; in part, this is due to lack of knowledge of what constitutes "good" or "bad" for particular indicators we are using. We have focused primarily on annually harvested herbaceous crops, and we have conducted pilot studies in North Carolina, Nebraska, and five mid-Atlantic states, using sites chosen on a probability basis with the NASS frame. We have developed our program with cooperation of several USDA agencies (ARS, NASS, and NRCS) as well as North Carolina State University. Several major problems have beset us: the lack of communication within and outside of EMAP led to insularity; the formalization of our conceptual framework and assessment methodology has proven to be more difficult than expected; and calibration of biological indicators against known measures of condition involves a circularity that we have been unable to escape. As the Agricultural Lands Group disbands, we hope we leave a legacy of useful information for others undertaking similar work.

Thank you for giving us the opportunity to tell ou about the Agricultural Lands part of the Environ-nental Monitoring and Assessment Program (EMAP). n this paper, we will discuss how our effort fits into he grand scheme of things, what our approach has been, some of the field work we have done, and who we have worked with. Along the way we will mention some "guideposts"—hard-earned wisdom we would like to pass on.

You may have already read something of EMAP in other papers, and you know that it is a research program that would have led to nationwide monitoring of all the major ecological resources in the United States. As part of that effort, our role was to assess the condition of US agricultural lands.

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EMAP-AGRICULTURAL LANDS AS ONE OF SEVERAL SIMILAR PROGRAMS

Our group is certainly not the only current effort to evaluate the agricultural resource in the US. Let us take a moment to describe some others, both to give you the broader picture and to help identify our unique place in that picture.

- The US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) conducts the National Resources Inventory (NRI) every five years across all nonfederal land in the country. This is an inventory of land cover and use, soil erosion, prime farmland, wetlands, and other natural resource characteristics, and they have recently taken steps to include measures of rangeland condition and soil quality.
- The USDA Economic Research Service (ERS) Area Studies program has investigated the link between agricultural practices and water quality. In cooperation with several US agencies, they used sampling points from the NRI to collect data from eleven watersheds across the country. The NRCS will use these data to simulate the effect of alternative farm management strategies on surface and groundwater (Robert Kellogg, personal communication). Meanwhile, the ERS will use the data to study how the choice of farming systems (technology, crop choice, chemical use) is related to environmental characteristics, economics, and government policies (Margriet Caswell, personal communication).
- The National Agricultural Statistics Service, in addition to involvement with Area Studies and EMAP and their many other duties, reports on farm pesticide use.

Each of these efforts differs from the others. The EMAP-Agricultural Lands program, in turn, is different from each of these in several important ways, such as our whole-ecosystem approach to indicator development and assessment, and our emphasis on biological indicators. Thus the programs are complementary rather than redundant. Redundancy in government is a common fear—and a common problem—and it is important to avoid it when establishing a new effort. Let us, then, offer this as a first guidepost: you will need to be able to explain quickly and clearly how you are different from all the rest. But part of that, we should add, is often explaining that you are making maximum use of existing information, that you are *not* trying to reinvent the science.

THE CONTEXT FOR EMAP-AGRICULTURAL LANDS

The Agricultural Lands group is an interagency effort that began in 1989. EMAP was created to answer the questions "Do US environmental policies work?" and "What new ones do we need?" by providing information on the extent and severity of environmental problems. We operate in a context of a national environmental policy whose ups and downs need no review for this audience.

We also exist in the context of the increasingly popular "sustainable agriculture" movement. This term has been used to describe many philosophies (Ruttan 1994) about how to remake agriculture so that current needs are met without jeopardizing resources for future generations. Many advocates define sustainable agriculture in terms of specific practices: reduced pesticide use, reduced tillage, increased reliance on local inputs, and so forth. Our group does not believe that any one of these alone defines sustainability, although we do agree that it is generally better to work with natural processes than to substitute for them.

While we work within these two contexts, our approach differs in several important respects. In contrast to many in natural resource management, we believe strongly that agricultural lands are intrinsically important, not of interest only for their impacts on other systems. On the other hand, in contrast to many in the sustainability school, we limit ourselves to the biophysical aspects of sustainability, while agreeing in principle with those who recognize economic and social dimensions (e.g., Conway 1987).

CONCEPTUAL APPROACH

In this philosophical setting, we have worked to develop a program that can provide information to policy makers on the overall condition and sustainability of US agriculture. Like the rest of EMAP, our mandate was to report on ecological condition. But how does one determine condition of an agroecosystem? Agricultural lands, especially fields, are continually and intensively managed. In ecological terms they are highly disturbed systems where succession is deliberately disrupted and large amounts of biomass are removed, although nutrient cycling, decomposition, photosynthesis, competition, predation, parasitism, and other ecological processes continue. There is no such thing as a "pristine agroecosystem," untouched by human hands, that we can hold up as the ideal all agroecosystems should be compared to. Instead, we have to examine the values society places on agricultural lands as well as the agroecosystem characteristics that support gratification of these values.

We have identified three societal values: (1) crop and livestock productivity; (2) the quality of agricultural soils, and the quality of the air and water both entering and leaving agricultural systems; and (3) biological diversity. Diversity has become a popular issue recently; it exists at many different scales, from the genetic diversity of the crops to the species diversity of the wildlife living in and around fields. Each of our indicators rests on one or more of these three values. Many of the indicators also relate to ecological processes, such as decomposition and nutrient cycling, which underpin the agroecosystem's ability to satisfy values. We are, or were, in the process of formalizing that conceptual framework.

INDICATORS

Ecological indicators in agricultural lands are a relatively new idea, but we have made some important inroads. In our indicator development, we have so far focused mainly on one class of agricultural resource, annually harvested herbaceous crops, which occupy just under 15% of the land area of the US (calculated from 1992 Agricultural Census data). We have not yet addressed pastures and orchards.

Since crops are the reason these systems exist, crop productivity is the clear place to start, but crop yields are already monitored by the National Agricultural Statistics Service. Instead, we wanted to know how yields relate to yield potential, and whether yields are being maintained or increased only at the cost of large or increasing subsidies to the system. Two indices were calculated for each sample location: the ratio of actual yields to historical averages, and the ratio of yield to the quantity of nitrogen applied in the form of fertilizer and manure. Crop growth is highly dependent on soil characteristics, weather, and management, so we have been working on ways to use mathematical models to account for some of these known effects, revealing underlying *ecological* differences.

In agricultural systems, soil has several functions: to support plant growth, to hold and break down agricultural chemicals and thereby protect surface and ground water, and to regulate water flow in the landscape (see, e.g., Doran and Parkin [1994] for a discussion). To address how soils are performing the first function, our scientists have modified a *soil rating for plant growth,* in which site measurements of bulk density, pH, organic matter, clay content, erosion class, drainage class, and much more are gathered into an index of the potential of the soil as a medium for plant growth. This observed value for a field can then be compared to an expected value based on previously measured parameters for similar soils. Where the index does not meet expectations, we infer that degradation has occurred. For the second function, environmental buffering, an effort is underway to adapt a pesticide leaching risk index to our sampling scheme, using both soil characteristics and information on pesticide applications. We have started work to add extra dimensions to these indices with measures of soil microbial activity, a new area of research for us.

We are not as far along with indicators of water and air quality. We consider farm ponds to be an important and easily-overlooked water resource, and have done some preliminary work on chemical and biological (benthic invertebrate) indicators of the health of farm ponds, which we believe reflect the quality of catchment areas. Also, we have been involved in the development of a biomonitoring system for ozone that uses clones of white clover (*Trifolium repens*) (Heagle et al., 1994). By comparing the growth and chlorophyll content of known ozone-sensitive and resistant clones, the biologically active ozone dose is measured.

Many of our indicators come under the umbrella of diversity. The diversity of crops in a region and the rotation of crops on individual fields are two simple indicators we have used. One of our longest-running efforts is in the area of nematode diversity. These microscopic roundworms occupy key positions in the soil food web and are closely tied to soil quality. Various indices based on trophic groups of nematodes, both plant-parasitic and free-living, are able to discriminate disturbed and undisturbed sites. One of our newest indicator categories is insect diversity, and for that we are looking at ants sampled in and near crop fields. We have also been addressing bird diversity, initially by examining habitat. In the Great Plains region of the US, windbreaks (rows of trees and shrubs that shelter fields and buildings) often represent the majority of the wooded cover in the agricultural landscape. We are looking at the potential and actual performance of windbreaks in the state of Nebraska (which is in the Great Plains) as breeding habitat for birds.

SAMPLING FRAME

As we have implied in discussing these indicators, we have moved from theoretical development to actual testing in large-scale field studies. Our indicators have been tested in various combinations in a series of Pilot Field Programs, starting in North Carolina in 1992, then in Nebraska in 1993 and 1994, and back on the east coast for multi-state projects in the Mid-Atlantic area in 1994 and 1995. Clearly we could not collect data on *all* the annually harvested herbaceous cropland in those regions, so we chose sample sites on a probability basis. In several other papers, you may have read about the EMAP hexagon sampling frame; although we tested a modified version of the hexagon frame, we opted to use the National Agricultural Statistics Service's area frame. We found that it was more efficient because it samples more intensely where agriculture is more common.

ASSESSMENT

As it stands, our indicators are only loosely tied together. We are still in the early stages of learning to combine them into a coherent assessment of the condition of agricultural lands. In the course of developing an assessment framework, many challenges have faced us, from the initial decisions of what is important in an ecosystem and what the proper indicators are, to the later interpretation issues of weighing the relative importance of each indicator and determining how best to combine measures into an overall determination of "good" or "bad" condition (alternatively, "sustainability" or "unsustainability") for a site or region. One of the greatest problems we have faced has been assigning cutoff points for distinguishing "good" from "bad" for most of our indicators. However, we would like to note that in soils, where perhaps there is a bit more history in interpretation, our scientists have made a notable effort to bring the three types of soil properties (physical, chemical, biological) into a single report card for each soil function. In soils we have also done some preliminary work using relatively undisturbed sites, such as pastures, as reference sites. Let us, here, come back to the idea of guideposts, and mention that assessment issues need to be worked out at an early stage, both to orient subsequent research and to lend credibility to the science.

Having outlined our approach, we will briefly describe our organization and then plant a few more guideposts.

INSTITUTIONAL ARRANGEMENTS

The EMAP-Agricultural Lands program has created a network of scientists from several federal agencies as well as universities. Our main staff of a dozen scientists and statisticians are located in a USDA facility on the campus of North Carolina State University in Raleigh. The effort to develop and test our indicators was carried out through an Interagency Agreement between EPA's Office of Research and Development and the USDA Agricultural Research Service, which administered the program. Most of the staff were hired through specific cooperative agreements with North Carolina State University. The technical director's position is through the Agricultural Research Service, and the indicator lead for soil quality is with the Natural Resources Conservation Service. Our bird sampling was conducted in cooperation with the University of Maine. One of our most important working relationships has been with the National Agricultural Statistics Service, who provided the statistical frame, helped us to develop our

questionnaire, provided field personnel for data collection, and were willing to work with us on some thorny issues of data confidentiality. And let us present a third guidepost here: monitoring often entails working with landowners, and it is important to be sure that you can get the data you need *and* that you can use it in the way you want. If not, you will need to make accomodations for any constraints on your data. In our case, we had to promise growers that their names and addresses would be kept confidential to ensure we were getting honest answers. That meant we could not release locational information, or anything else that could identify growers, in a public release dataset.

DIFFICULTIES

While we enjoyed some success, many problems beset us. Three are worth mentioning here as the last three guideposts—a warning to others of what to avoid.

- First, there was a lack of communication (and of incentive to communicate) both inside and outside of EMAP. Individual resource groups became their own kingdoms, and contact was lost with others who might make good use of the data. Eventually we became our own clients. Though we attempted to improve our interagency relations, powerful forces frustrated this effort for most of the life of the program.
- Second, the conceptual framework has receded from us like the fruit receding from Tantalus. We have tried for years to develop a good, scientifically defensible way to tie everything together, but we are not there yet. Clear and specific questions from policy makers might have helped; on the other hand, we understand the need to think in new directions that they might not have considered.
- Third, most of our biological indicators suffered from the problem of circularity. The question remains, if you calibrate a biological indicator against some other, known measure of condition, why not just use the known measure? We highly recommend choosing indicators, including biological ones, that are either directly of value to people or are clearly tied to something of value—monetary or otherwise.

CONCLUSION

Unfortunately, we ourselves will not have the opportunity to resolve these problems. Because of recent reorganizations within EMAP, the Agricultural Lands group will be dissolved in the near future. Interagency discussions on the development of a national environmental monitoring network are underway in the US. Because this network will rely on existing monitoring efforts and research sites, it should improve communication and reduce the duplication of effort. It is unclear what role, if any, EMAP will play in this new network.

In summary, we in the Agricultural Lands Resource Group faced the challenge of developing a set of indicators of the condition of crops, soils, and landscapes, while struggling to develop an ecological and common-sense framework for monitoring and assessment. While we were not entirely successful, we hope that our experiences will serve as guideposts to those of you who will undertake similar work.

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Estrategias y Objetivos del Monitoreo de Plagas Agricolas en el Noroeste De México

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RESUMEN.—El escaso conocimiento temporal y espacial del comportamiento de las plagas y enfermedades en los cultivos ocasionan el uso indiscriminado e inadecuado de plaguicidas, causando graves daños al ambiente y a la salud humana. El monitoreo es el medio por el cual se realiza un seguimiento sistemático de plagas y enfermedades en agroecosistemas, así como de los factores bióticos y abióticos con los que están relacionados, buscando y promoviendo la sanidad integral y conservación de los agroecosistemas. Mediante su planeación y ejecución se logran los fundamentos para una aplicación adecuada de los plaguicidas, lo que coadyuva a generar métodos de agricultura sustentable. Para la factibilidad de operación de los programas de monitoreo, es necesario definir bajo ciertas condiciones el Marco Operativo así como el Mecanismo o Instrumento de Ejecución. Mediante dichos instrumentos se definen explícitamente las tareas y responsabilidades de los participantes, mismos que deberán involucrar a diferentes instituciones y especialistas. De ahí que en el presente documento se plantean propuestas para una planificación adecuada del monitoreo de plagas, con el fin de que el control de las mismas sea más eficiente.

Palabras Clave: Monitoreo, agroecosistemas, control químico, plaga, plaguicidas, plaguicidas agrícolas, Manejo Integrado de plagas, *Bemisia spp.*

ABSTRACT.—The poor and inadequate knowledge about the agricultural pests dynamics and behavior causes misuse and abuse of insecticides and other pesticides, striking the environment, natural resources and human health. In this sense, monitoring must be considered as the main tool to assess pests presence and their effects on agroecosystems, seeking and promoting an integral welfare and conservation of agroecosystems. Through successful monitoring, it becomes more feasible an adequate pesticide application, towards the development of a sustainable agriculture. The definition of practical monitoring schemes requires an "Operational Framework" and also an "Execution Plan". Such tools must define in a clear and explicit way the different objectives and responsibilities, in time and space, of all collaborators in an specific monitoring project. In general, a monitoring plan or project should involve different specialists and institutions in a study region. Finally, in this work we present several proposes for an adequate planning of agricultural pests monitoring, seeking an efficient and integrated pest control, for protecting agroecosystems.

Keywords: Monitoring, agroecosystems, chemical control, pests, pesticides, agricultural pesticides, Integrated Pest Management, *Bemisia spp.*

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INTRODUCCION

En los últimos años, a consecuencia del incremento de la cultura ecológica de la población, así como del cambio en la política y legislación que en materia de protección al ambiente se ha dado en el país, la percepción sobre la importancia real que reviste el monitoreo de los ecosistemas frágiles se ha incrementado sensiblemente.

En el caso de la protección y conservación de los agroecosistemas, es claro el riesgo de contaminación por agroquímicos que potencialmente existe por un eventual mal uso y abuso de plaguicidas. Los grandes objetivos que implícitamente deben perseguirse mediante el monitoreo de agroecosistemas, incluyen necesariamente la búsqueda y promoción de la sanidad integral y la conservación de los agroecosistemas. Tales objetivos conllevan finalmente a la obtención de óptimos niveles de producción agrícola y lograr la protección de la salud humana, así como el bienestar social.

Entre los objetivos particulares que debe contemplar un esquema de monitoreo de agroecosistemas, pueden mencionarse los siguientes:

- Evitar la proliferación de las plagas con importancia económica.
- Detectar el uso inadecuado de plaguicidas y equipos de aplicación.
- Evitar el uso excesivo de agroquímicos.
- Detectar a tiempo la incidencia de enfermedades en plantas y animales.
- Identificar los factores abióticos que intervienen en los procesos de proliferación e incidencia de plagas.

La consecución de dichos objetivos indudablemente proveerán las herramientas para desarrollar métodos de agricultura sustentable, mediante los cuales la conservación de las cuencas hidro-agrícolas será más factible. Para lograr lo anterior, los esquemas de monitoreo de las plagas y enfermedades regionales clave, deben alcanzar de una manera oprtuna las siguientes metas:

- Detectar las plagas relevantes en zonas agrícolas, rurales y urbanas.
- Determinar los niveles de infestacion en cada caso.
- Detectar las tasas de avance y pronosticar su dispersión en cada ciclo.
- Determinar los niveles de resistencia a los plaguicidas comunes.

Entre los conflictos generados por el uso indiscriminado e irracional de plaguicidas que se **evitarían** mediante la implementación de esquemas adecuados de monitoreo, pueden mencionarse los siguientes:

i. Daño a la salud de los habitantes y al medio, incluyendo al suelo, agua superficial y subterránea, aire, vegetación y fauna.
ii. Desarrollo de resistencia por parte de las plagas agrícolas.
iii. La posibilidad de que los países exportadores de agroquímicos reimporten residuos que superen la norma aceptable, a través de los alimentos que potencialmente les pueden comprar a sus clientes.
iv. Efectos negativos sobre la disponibilidad de recursos financieros y sobre la produccion: Aumento de los costos directos, reducción de las utilidades, disminución de la vida util del agroecosistema.

Qué representa e implica el MONITOREO EN AGROECOSISTEMAS?

Por definición, el monitoreo es un muestreo sistemático, periódico y calendarizado que se realiza con un fin determinado. Un monitoreo va más allá de los alcances comunes de un proyecto; se trata de un esfuerzo interinstitucional para resolver una problemática común, a una escala regional.

Por su parte, el término "Agroecosistema" se define como parte del ambiente que ha sido modificado para beneficio del ser humano y la producción de sus cultivos agrícolas y forestales. Los componentes del agroecosistema comprenden todos los organismos y recursos disponibles en la región cultivada:

....Los cultivos sembrados, el suelo, agua circulante, su flora, fauna y microfauna, la energia natural y artificial utilizada en el sistema, el ambiente físico y químico, el ser humano, y demás componentes participantes.

Ocasionalmente...... un subcomponente del agroecosistema llega a ser "dominante y pernicioso", como una maleza, vertebrado, microorganismo o un artrópodo herbívoro. De esta forma, genéricamente los artrópodos herbívoros o bien los vertebrados pueden convertirse en una "plaga", que se define

como todo organismo cuya presencia, por su densidad poblacional y hábitos alimenticios, resulta perjudicial para el hombre. Tal situacion *irregular* va en contra del propósito productivo de la agricultura, cuyo interés primordial es obtener el producto cosechable sin la competencia de otros consumidores.

Siendo el "agroecosistema" un conjunto artificial, manejado con el fin de maximizar los rendimientos útiles para el ser humano, debe cuidarse y conservarse a mediano y largo plazo, evitando su deterioro.

IMPORTANCIA DEL MONITOREO DE PLAGAS DE ARTRÓPODOS.

Existen varias plagas de insectos, ácaros y otros artrópodos de gran importancia económica a nivel mundial. El hombre ha luchado de manera permanente contra dichos artrópodos, ya que cuando aparentemente logra controlar alguno de ellos, surgen nuevas especies-plaga, a pesar de los esfuerzos para regular la importación de sus hospederos ya sean plantas o animales (Alatorre, no publicado).

Las plagas tienen gran capacidad para desarrollar adaptaciones en su ciclo de vida o adquirir resistencia a los diferentes compuestos químicos usados para su control. Tal situación genera como resultado una gran pérdida económica, ecológica y ambiental, sobre todo en aquellos países que manejan una agricultura extensiva. El uso no planificado de dichos compuestos químicos representa una contínua erosión agroecológica en el control de las plagas agrícolas en diversas regiones del mundo.

Con objeto de combatir las plagas de la manera más eficiente posible, se ha establecido un esquema metodológico que facilita tomar las mejores decisiones para su control: El "Manejo Integrado de Plagas" (MIP), el cual integra una gama de técnicas que permiten minimizar los efectos de los plaguicidas en el medio ambiente (Burn *et al.*, 1987).

Es importante que en una área agrícola, donde se usan de manera intensiva los insecticidas, se evalúen periódicamente los niveles de resistencia alcanzados por las plagas (Ortega, 1990). Lo anterior permite diseñar estrategias que conducen al manejo integrado, eliminando productos que más que controlar, sólo contaminan el ambiente. Así, surge el manejo de resistencia a insecticidas (MRI), el cual conjunta las estrategias preventivas, que tienen como objetivo la conservación de la "susceptibilidad" en las especies (Lagunes y Vázquez, 1994). Por lo anterior, se podrán mantener vigentes los insecticidas para los que ya existen poblaciones de insectos resistentes, evitando el desarrollo de razas o variedades de plagas resistentes.

La determinación periódica y monitoreo de los niveles de resistencia o susceptibilidad debe cumplir dos objetivos:

- El primero de ellos consiste en detectar lo antes posible la aparición de genotipos resistentes, mientras que,
- El segundo tiene la finalidad de determinar la evolución de la resistencia mediante la cuantificación del cambio en el nivel de susceptibilidad en la población hacia un insecticida determinado, por medio de bioensayos de los cuales se obtienen la CL50, DL50 o TL50 (Ortega, 1990).

El nivel de resistencia varía con el insecticida, la plaga, hospedero y el lugar; las condiciones ambientales pueden llevar a una fluctuación en la susceptibilidad. Dicha variación también se debe a las diferentes épocas de cultivo, en que puede haber una excesiva, poca o nula aplicación de insecticidas (Cortez, 1994; Ortega, 1990). Por tal razón, es necesario conocer los niveles de resistencia a través del tiempo en una región determinada.

Asimismo, una vez detectados los niveles de resistencia es necesario conocer los mecanismos fisiológicos involucrados, para poder definir que insecticida utilizar, de tal manera que se pueda incrementar la vida útil de dicho compuesto (Lagunes y Rodríguez, 1989).

Existen varios países en donde se han implementado estrategias de manejo de resistencia a plaguicidas, mediante la regulación de factores operacionales como reducción de dosis, modificación en la frecuencia de las aplicaciones, o aplicación selectiva de los insecticidas.

En cualquier estrategia de manejo de resistencia a insecticidas, el bioensayo constituye la herramienta básica. Para la verificación del efecto de las medidas operacionales adoptadas, es importante que haya uniformidad en los métodos de bioensayo para la detección de resistencia, ya que esto se hace fundamentalmente por comparación. En este sentido existe un esfuerzo importante, realizado por diferentes organizaciones a nivel mundial; sin embargo, no existe suficiente uniformidad en ello, ya que cada investigador adiciona nuevos elementos al

método, lo cual impide un esfuerzo colectivo en la detección de resistencia a plaguicidas (Lagunes y Vázquez, 1994).

Una propuesta establecida por Vázquez-Navarro (1993) para el monitoreo de las plagas agrícolas, contempla los siguientes pasos secuenciales:

1o. Establecer estudios y monitoreos a nivel regional sobre las plagas clave,

2o. Elegir el estadio de vida del insecto y el método ideal para el bioensayo, y

3o. Obtener información para establecer las líneas de respuesta que sirvan de base para comparar poblaciones susceptibles y resistentes.

Con la sistematización y análisis de la información anterior se podrán aplicar las siguientes medidas:

- Establecer dosis discriminantes para definir el estatus de cada población plaga, para posteriormente liberar la información a fin de apoyar programas regionales de manejo de insecticidas, y posteriormente,
- Integrar los resultados en un banco regional de información que pueda ser utilizado a nivel nacional, por medio de programas de cómputo.

Dentro de los mencionados aspectos, en el noroeste de México actualmente se realizan estudios de monitoreo en las plagas-insecto más importantes de la región, como la mosquita blanca (*Bemisia argentifolii, B. tabaci*) y el picudo del chile (*Anthonomus eugenii*). Ambos programas se ejecutan en colaboración interinstitucional, lográndose a la fecha mantener poblaciones aisladas de tales insectos, para obtener líneas base que sirvan de referencia para conocer los niveles de resistencia alcanzados por dichas plagas.

En términos regionales, el monitoreo de artrópodos-plaga en el noroeste de México (nuestro caso particular), y en cualquier región del país, tiene como objetivo principal detectar los niveles de infestacion de plagas importantes que representen un daño significativo a la producción y a la calidad de los productos, tanto en campo como en almacén, con el objeto de aplicar las estrategias de control mas apropiadas.

FACTIBILIDAD DE OPERACIÓN DE LOS PROGRAMAS DE MONITOREO.

Para asegurar la factibilidad de realización y el éxito esperado al diseñar programas de monitoreo, deben previamente definirse claramente tanto el "Marco Operativo" como el "Mecanismo o Instrumento de Ejecución", por lo que deben tenerse resueltas las siguientes consideraciones:

En relación con el Marco Operativo:

- Quiénes o qué equipos de trabajo realizarán los muestreos sugeridos?
- Cuál deberá ser la frecuencia de muestreo?
- Que variables e índices capturar?
- Quien capturará y procesará la información?
- Cuales son los límites en tiempo y espacio?

Por su parte, el "Mecanismo o Instrumento de Ejecución" deberá ser aquel en el que se definan clara y explícitamente las responsabilidades y tareas específas de las instituciones e investigadores participantes, de tal forma que queden clara las metas a alcanzar en el corto y mediano plazo.

LAS PLAGAS CLAVE EN EL NOROESTE DE MÉXICO Y MEDIDAS DE CONTROL: RESULTADOS PARCIALES.

Actualmente las plagas que en la región noroeste se consideran como las más perjudiciales por sus efectos son las siguientes:

1) Grupo "MOSCAS DE LA FRUTA" (*Anastrepha ludens* y *Anastrepha oblicua*). Para esta plaga el método de muestreo ha sido la instalación de trampas en frutales. Las estrategias de control que se han aplicado son: (a) Liberación de moscas estériles, y (b) Aplicación de insecticidas, entre los cuales el de mayor uso es el malatión, mezclado con atrayentes proteinados (Aluja, 1985). Los hospederos naturales de *A. ludens* reportados para Baja California Sur son el mango (*Mangifera indica* L.), naranja agria (*Citrus aurantium* L.), naranja dulce (*Citrus sinensis*

L.), toronja (*Citrus paradisis* Macfady), lima-limón (*Citrus limetta* Risso), pomela (*Citrus maxima* (Burm)), y otras (Jimenez *et al.*, 1992). Los resultados han sido alentadores y positivos, principalmente en relación con la liberación de moscas estériles, ya que en Baja California Sur se han declarado tres municipios libres de la mosca de la fruta *A. ludens*.

2) Grupo de homópteros conocido como "MOSQUITA BLANCA". Insectos-plaga que recientemente han adquirido enorme relevancia por los daños que causa en cultivos extensivos, como el algodonero, en el que ocasiona frecuentemente pérdidas totales. Las especies que conforman este grupo (*Bemisia argentifolii, B. tabaci, Aleurothrixus floccosus, Tetraleurodes ursorum* y *Trialeurodes abutilonea*, Fam. Aleyrodidae) han desarrollado diversas cepas o razas adaptadas a cada región particular. Las estrategias de monitoreo de la mosquita blanca consisten en trampeos sistemáticos empleando trampas amarillas y muestreos calendarizados con red entomológica. El control principal en el noroeste de México es el químico, empleando los insecticidas paratión metílico, metamidofós y cipermetrina, entre otros, con diversos criterios y dosis de aplicación. También se empieza a aplicar el control biológico, empleando el depredador *Chrysoperla carnea* (Cortez, 1994).

RAZONES PARA LLEVAR A CABO MONITOREO DE PLAGAS CLAVE: EL CASO DE LA MOSQUITA BLANCA *(Bemisia tabaci, B. argentifolii)*.

Los insectos del grupo "mosquita blanca" son de ciclo de vida corto, la gama de hospederos es amplia y su nivel de plasticidad fenotípica y genotípica es alto. Cuenta con una efectiva adaptación del sistema enzimático a los insecticidas, tiene una alta velocidad de dispersión agrogeográfica, y con facilidad evade el contacto con los insecticidas aplicados. Aunado a ello, presentan una notoria variación de morfotipos, de acuerdo con la naturaleza de los hospederos y con las fluctuaciones climáticas. Asimismo, son vectores de enfermedades, lo cual es una de las principales causas que origina enormes pérdidas en cultivos de granos y forrajes, hortalizas y frutales. *B. tabaci* transmite una enfermedad viral llamada "enchinamiento del algodonero", que se ha presentado en el Valle de Santo Domingo, B.C.S., en Mexicali, B.C., costa de Hermosillo, Son., y en el Valle del Yaqui, Son., en el noroeste de México país (Pacheco, 1985), elevando los costos de control (Rodríguez y Loya, 1987).

REQUISITOS PARA EJECUTAR EXITOSAMENTE PLANES DE MONITOREO.

Entre los diversos aspectos que deben cumplirse para que los programas de monitoreo sean exitosos, deben considerarse las siguientes actividades:

- Definición de grupos de trabajo y se sus límites geográficos de acción.
- Objetivos globales y particulares.
- Colecciones de referencia de las plagas monitoreadas.
- Bancos de datos de fácil acceso.
- Estandarización de técnicas de determinación de especies y biotipos.
- Estandarización de las unidades de medición y de muestreo.
- Mesas de trabajo locales para analizar la información colectada.
- Medidas preventivas y correctivas.
- Definición de responsabilidades y tareas, individuales e institucionales.
- Foros regionales o internacionales de análisis y discusión.

El personal encargado del monitoreo debe estar compenetrado con las ventajas y limitantes de los métodos de muestreo y sus unidades de medición. El método de captura o muestreo más apropiado para un caso particular debe satisfacer los objetivos que se persiguen en dicha situación específica.

CONCLUSIONES

Aún cuando el agroecosistema es sencillo, su correcto manejo requiere mantener la estructura que lo distingue. En efecto, en todo sistema hay una variedad de especies aparentemente irrelevantes para el éxito de la cosecha y que sin embargo son claves

para la salud general del mismo. La diversidad, sea amplia o estrecha, tiene que mantenerse para el equilibrio de la poblacion de artrópodos. Es dicha diversidad de organismos la que se pierde con el uso inapropiado de plaguicidas o con cualquier otra práctica agrícola mal ejercida.

El MIP, así como el MRI, requieren la dirección de especialistas en agroecosistemas porque cada uno de sus componentes es una variable por evaluar, según la cantidad y distribucion de las especie dañinas. El correcto manejo del agroecosistema no debe ignorar ninguna de las variables agroecológicas. Una decisión para controlar una plaga debe evaluar todos los aspectos del sistema. Los tratamientos basados en plaguicidas son en realidad programas predeterminados: Los recomiendan los fabricantes de agroquímicos a través de la publicidad, la asesoría técnica y otros medios de comunicación, pero es una maniobra que solo proporciona frutos parciales en el corto plazo y negativos a largo plazo. No siempre es fácil decidir el momento para iniciar un programa de MIP; aunque parece sencillo comparar el costo del daño con el costo del programa de monitoreo y control, siempre hay numerosas variables que evaluar:

1. Las medidas de control se ejercen para prevenir daños futuros, pero su estimacion casi nunca es excacta.
2. En los cultivos de largo plazo es importante estimar la conveniencia de repetir algunas medidas de control.
3. Frecuentemente el efecto de la medida de control sobre la plaga no es predecible; p. ej., el ciclo o época en que la misma puede reaparecer.
4. Los costos del control pueden variar en los materiales o mano de obra.
5. Los recursos necesarios para ejecutar un programa de control frecuentemente tardan en reunirse; asimismo, un equipo de trabajadores muy especializados pueden requerir cierto tiempo en acordar ciertas decisiones. Mientras tanto, la plaga puede continuar proliferando.
6. Ocasionalmente las mismas medidas de control de la plaga afectan tambien al cultivo; algunas veces por medio de la fitotoxicidad o del equipo (daños mecánicos). Tales costos deben estimarse de antemano.
7. Las medidas de control pueden tener efectos no esperados, como el exterminio de insectos beneficos que son útiles en diversos aspectos.
8. Pueden originar igualmente efectos en el mercado; p. ej., la saturación y sobre-oferta de un producto que localmente fue liberado de sus plagas.

Determinar el daño económico no siempre resulta muy exacto. Se requieren adecuados modelos matemáticos para manejar todas las variables, y especialistas en agroecosistemas para iniciar un programa que incluya las variables y factores involucrados. No debe olvidarse que mas allá de la resistencia o susceptibilidad de las plagas, el principal riesgo del mal uso de plaguicidas apunta finalmente al deterioro de la salud humana. El MIP tiene como fin manejar las plagas empleando las técnicas disponibles de manera compatible, para no impactar el agroecosistema.

Finalmente, para alcanzar una mayor concertación entre los investigadores e instituciones involucradas en el control de plagas, se presentan las siguientes propuestas, en el entendido de que habrán de realizarse los ajustes pertinentes, según las características de los propios equipos de trabajo:

(a) Creación de comités interinstitucionales, regionales e internacionales, para el monitoreo y análisis de los factores relevantes para el estado de sanidad de los agroecosistemas; y,
(b) Ejecución de proyectos específicos para la solución mediata y a largo plazo de problemas fitosanitarios de interés común, sean regionales o de ámbito internacional.

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SUBJECT V: PARAMETERS AND METHODS FOR USE IN ASSESSMENT OF SINGLE AND MULTIPLE RESOURCES

Four concurrent groups of practitioners representing national ecosystem resource groups addressed the following topics: (1) Development and Evaluation of Biological and Ecological Condition Indicators, (2) Comparison of Design and Statistics Approaches, (3) Information Quality Assurance and Information Management Systems, and (4) Analysis, and Assessment and Reporting. Platform presentations were supplemented by Panel discussions.

Design and Development of Environmental Indicators with Reference to Canadian Agriculture

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1.0 INTRODUCTION[5]

We live in a period of heightened awareness and concern about the sustainability of ecosystems and the issues which are fuelling concern are varied and complex. How ecosystems are used and managed by humans will affect their ability to provide social, economic and environmental benefits, such as renewable resources (as in the case of fisheries, forestry and agriculture), clean air and water, habitat for wildlife, landscape for recreation and so forth.

Managing ecosystems sustainably requires a sound understanding of what the stressors are, the linkages among them and the nature and severity of their impacts. Ultimately, human activities must be managed in a manner which respects ecological principles and limits while at the same time maximizing social and economic benefits.

The challenges of ecosystem management are increasing pressures on both the generators and users of environmental information. Generators of information include the scientific community in its broadest sense: researchers and analysts from diverse social, ecological and economic disciplines. Their challenge is to help define and increase understanding of the issues, the expected ecological consequences of human activities, and ecological limits and thresholds. Users of information include decision-makers at all levels, from ordinary citizens to senior decision-makers in government and industry. Their challenge is to take decisions and set policies that achieve an optimal balance between what are often conflicting sets of objectives as stakeholders have various objective sets and frequently desire different policy outcomes.

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[5] *A modified version of this paper was originally presented under the title "Role and Nature of Environmental Indicators in Canadian Agricultural Policy Development" at the June 1995 symposium on environmental indicators of the Resource Policy Consortium in Washington, D.C. .*

Complex tradeoffs are involved in many policy decisions and these have to be discussed and weighed in an open forum. In essence, policy-makers must have at their disposal information about the issues of concern and methods to discover the weights that stakeholders attach to those issues. Although the environmental policy process is becoming more broadly based, the analytical capability has not historically kept pace with the need to develop, assess and integrate environmental information into decision-making processes.

This paper reviews some basic principles of environmental indicator design and summarizes work underway in Agriculture and Agri-Food Canada (AAFC) to develop agri-environmental indicators (AEIs) for Canadian agriculture. Concepts and applications of environmental indicators are reviewed in section 2, the approach being pursued by AAFC to develop AEIs is presented in section 3 and examples of results achieved to date are identified in section 4. The paper concludes with some general points concerning the implications of the work on AEIs to ecological monitoring and assessment.

2.0 INDICATOR CONCEPTS AND APPLICATIONS

2.1 Definition and Functions of Environmental Indicators

The term "indicator" has achieved widespread use in many disciplines, particularly in economics, where work to develop economic indicators has been ongoing for decades. In the environment field, formal work to develop environmental indicators is much more recent.

As a result of diverse national and international initiatives in this area (see Hardi and Pinter, 1995) several definitions or terms have emerged, including environmental indicators, environmental performance indicators, ecosystem health indicators and natural resource indicators, among others. These terms are closely linked and generally express similar concepts.

Environmental indicators can be defined as measures of change in the state of the environment, or in human activities which affect the state of the environment, preferably in relation to a standard, value, objective or goal (United States Environmental Protection Agency, 1972). For agriculture, AAFC has modified this definition as follows:

"A measure of change in the state of environmental resources used or affected by agriculture, or in farming activities which affect the state of such resources, preferably in relation to a standard, value, objective or goal".

The functions of environmental indicators have been described by several analysts and institutions (Adriaanse, 1993; OECD, 1993; Hammond et al., 1995). Indicators can be seen as succinct expressions of information or as tools to deliver information to decision-makers in a useable, understandable form. The OECD (1993) distinguishes between indicators and data by adding that their significance extends beyond the parameters that are directly measured by the indicator, thus they have a broader meaning than data alone.

Desirable characteristics of indicators include policy relevance, scientific rigor and replicability, regional sensitivity (particularly in a country as large and diverse as Canada) and feasibility (in terms of cost and access to required data). Adriaanse (1993) also distinguishes between retrospective and prospective indicators. Retrospective indicators measure historical change to the present while prospective indicators report the predicted direction of change based on assumptions about future policy and market scenarios. Retrospective indicators provide a base on which to develop prospective indicators thus both types of indicators are similar; conceptually, it is the historical and predictive focus which distinguishes them.

If environmental indicators are useful to policy-makers and stakeholders, they must:

- assess to what degree key agri-environmental issues are being addressed and objectives met;
- help to identify areas and resources at risk;
- help to design and target strategies and actions to ensure all costs are appropriately internalized; and
- facilitate communication among stakeholders, and between stakeholders and policy makers, on setting appropriate policy responses, especially when it comes to evaluating tradeoffs that might have to be made.

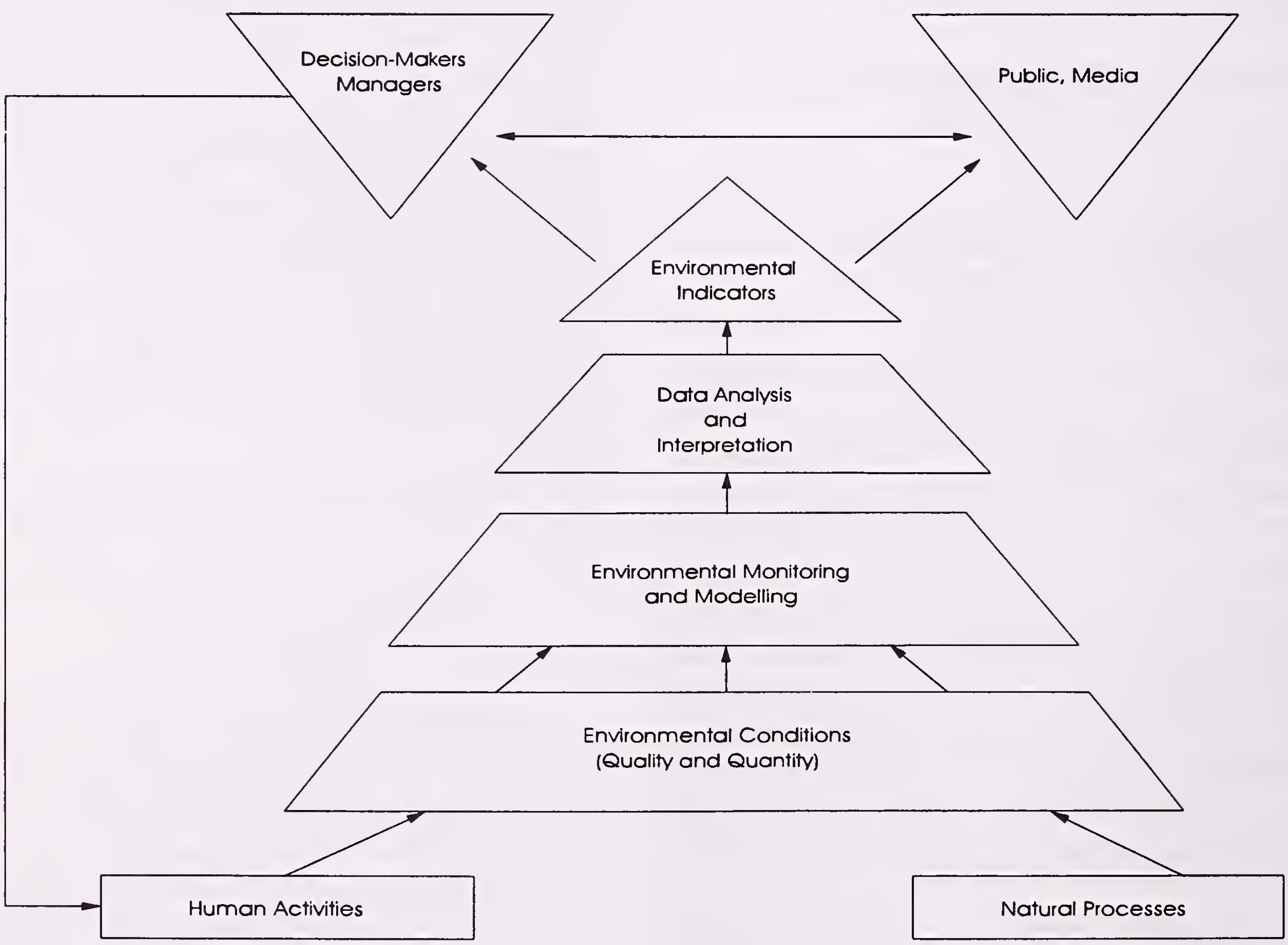
The recognized need to develop environmental indicators does not derive from a naive view that these will allow a consensus to be achieved or that in the past environmental considerations were not factored into decisions that were made. They will allow better measurements of whether priority issues have been adequately addressed, how stakeholders view the tradeoffs that might be involved, where inconsistencies exist, and where information is lacking.

2.2 Linkages Between Indicators, Environmental Monitoring and Assessment

As illustrated in Figure 1, indicators are a key link in the information development and delivery cycle. To develop indicators, methods of collecting and interpreting relevant data must be available, hence both monitoring and assessment methods are key inputs to the indicator development process.

Environmental monitoring can be defined as the repetitive observing of one or more environmentally-related parameters according to pre-arranged schedules in space and time using comparable methodologies for data collection. Design criteria to consider for maximizing the utility and value-added of environmental monitoring have been reviewed by Philips and Segar (1986), Shalski (1990), Wolfe (1987) and the National Research Council (1990), among others. Data obtained from monitoring are essential to indicator development, but it must be recognized that raw or excessively detailed data are meaningless to decision-makers and the public until summarized and interpreted. Methods of presenting, interpreting and aggregating data over time and space are needed.

An ecological approach to the spatial aggregation of data is outlined in section 3.2. Regarding interpretation, many practitioners stress that indicators derived from monitoring data should be linked to mea-



Source: Modified from Kerr, 1990

Figure 1. The relationship between environmental information and decision-making.

surable objectives and reference thresholds. Reference thresholds associate closely with objectives and aid with interpretation of data.

Environmental quality as a concept is strongly influenced by human values. Environmental objectives articulate these values while reference thresholds quantify them by identifying ranges of desirable or undesirable conditions or activities (eg., normal, problem, critical and irreversible (Gelinas and Slaats, 1989). As used here, a reference threshold can be any of the following:

- an environmental quality guideline, objective or standard, such as water quality guidelines for contaminants in water;
- a human activity target or goal, such as a goal to increase use of conservation tillage on erosion-prone soils;
- an ecological threshold, such as a minimum population size required for a given species in a specific area.

Environmental indicators juxtapose monitoring data against threshold levels of environmental quality and, in so doing, provide information on whether objectives are being met and whether conditions and trends are acceptable, improving or deteriorating.

Another consideration is whether monitoring should focus on ecological change, on human activities (i.e. on behaviour) or on both. Monitoring of ecological change directly reveals conditions and trends in the environment, eliminating any uncertainty about the nature and severity of environmental impacts. A major disadvantage, however, is the cost and complexity of such monitoring. Another approach is to monitor human activities and to infer from behavioral information what may or is likely to be happening in the environment or in ecosystems. A major advantage of this approach is that established statistical and other agencies already collect information on human activities of environmental significance. However, this "risk-based" approach requires a solid understanding of the linkages between human activities and environmental impacts. In order to present decision-makers with a good understanding of cause and effect linkages, it is likely that, in many cases, both approaches and information sets will be required for a comprehensive monitoring and indicator program.

3.0 ENVIRONMENTAL INDICATORS FOR CANADIAN AGRICULTURE

3.1 Conceptual Framework

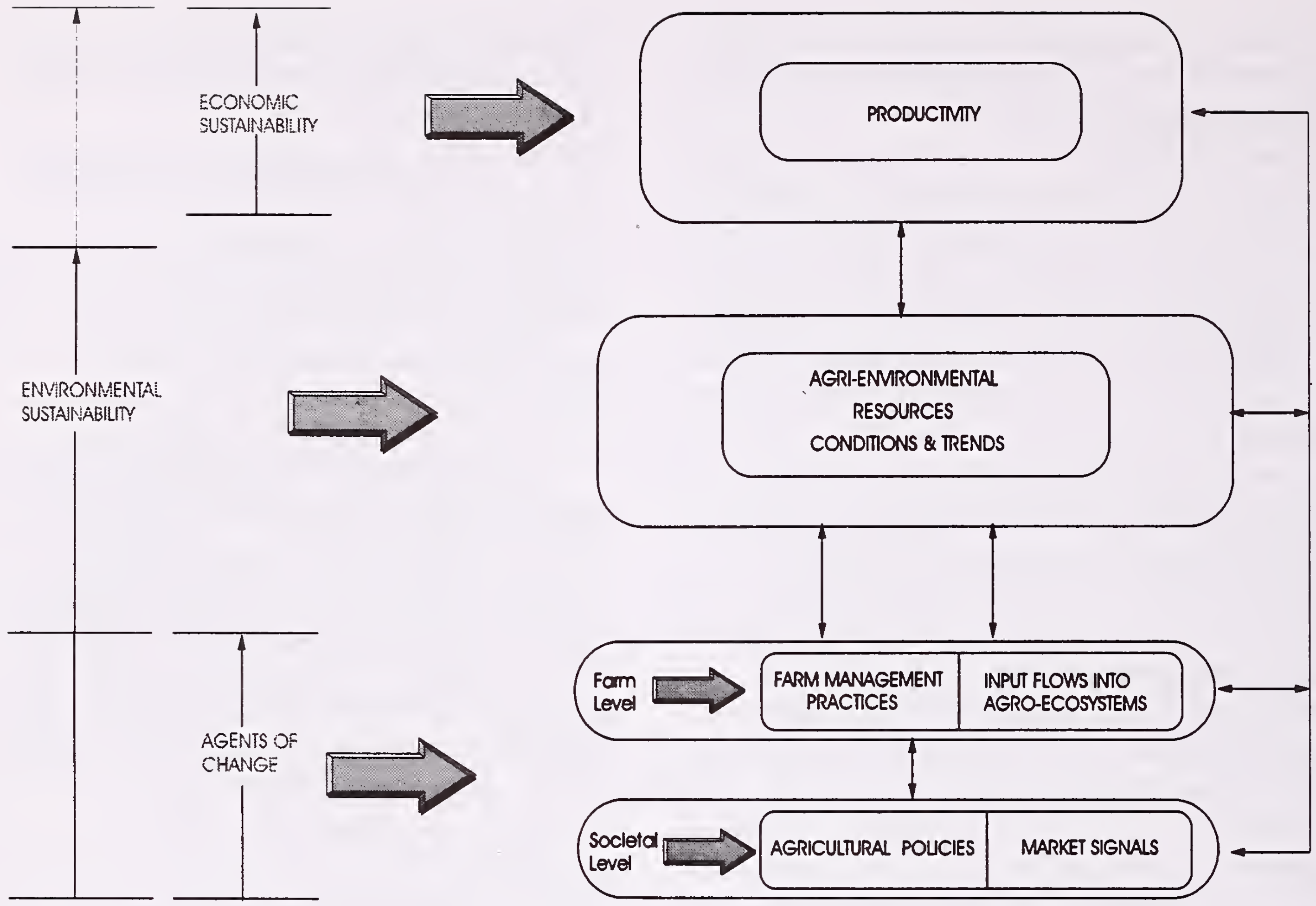
When developing indicators, a framework is required to structure analysis and to encapsulate broad linkages between activities and effects. For agroecosystems, the conceptual framework used must reflect the nature and key attributes of agroecosystems as well as the linkages between these attributes.

Various definitions of the term agroecosystem have been formulated. For example, the Federal-Provincial Agriculture Committee on Environmental Sustainability (1990) defined an agroecosystem as "communities of living species together with the living resources that sustain them, that interact directly or indirectly through the environment and that have established a balanced or stable equilibrium under an agricultural regime".

Agroecosystems are ecological systems that are distinct from "natural" ecosystems in several important ways. The most fundamental distinction is that agroecosystems are managed ecosystems designed primarily for the production of food and fibre. They are usually skewed to favour one or more dominant species of plant or animal but they also provide other benefits, such as the provision of habitat for wildlife, recycling of nutrients and storage of elements such as carbon.

Agroecosystems vary tremendously by production type and much of this variability stems from variability in the environment itself, for example, among soil types, land topography and climate. They encompass environmental resources such as soil, water and biodiversity and are intimately linked with other environmental media, such as the atmosphere. How agroecosystems are managed has implications for the health of environmental resources both within and adjacent (or external) to them.

After considering various frameworks, AAFC is using the framework illustrated in Figure 2 to guide its work on agri-environmental indicators. This framework is based on a framework originally proposed by researchers in Australia (Hamblin, 1991). Like similar frameworks such as the OECD Pressure-State-Response framework (OECD, 1993), it is based on a concept of causality. The framework is cyclical and its rationale is as follows:



Source: Modified from Hamblin, 1991

Figure 2. Conceptual framework for agri-environmental indicators.

- The management decisions and practices employed at the farm level, such as land use, input use, land management practices and types of crops grown, are fundamental to sustainability and are influenced by the economic and policy signals received by producers from the marketplace and from governments. Other factors, such as the availability of technology, cultural preferences and local resource conditions also influence these decisions and practices.
- The farm-level decisions and practices adopted can have both beneficial as well as adverse environmental impacts, both on on-farm and off-farm environmental resources.
- The state or condition of the resource base used by agriculture (e.g. soil, water, biodiversity), in combination with other factors such as improved genetics and climate, will affect farm productivity and competitiveness.
- Changes in the productivity of agriculture and in the condition of the resource base may trigger societal responses in the form of policy decisions and farm-level actions.

In developing AEIs, particular emphasis is being placed on indicators which track farm-level resource management and the relationship between management and changes in the condition of the resource base used or shared by agriculture. Modelling initiatives are also being pursued to link management actions and their environmental impacts with policy and economic signals, thus closing the conceptual loop between agents of change in agroecosystems and their potential environmental effects.

3.2 Spatial Considerations

The issue of spatial scale presents a significant challenge in indicator development. A hierarchy of spatial scales exists, ranging from the "lower levels", such as the plot or field scale, to "higher levels", such as a major ecological zone or political jurisdiction. It is theoretically possible to collect data and report

indicators at a range of scales, but in practice constraints related to data availability and the ability to extrapolate data often limit the choice of scales at which any given indicator can be calculated and reported. In addition, at various levels in a given system different characteristics and processes may predominate and those that are important at one level, such as herbicide dynamics at the soil-root interface (lower level), may be irrelevant at the regional (higher) level (MacDonald and Spaling, 1995a).

Selection of an appropriate scale for reporting AEIs is intimately linked to the intended uses (and anticipated users) of the information: different users require information at different scales for different uses. Producers, for example, manage primarily at the farm and field levels but are also concerned about policy and market developments at regional, national and international levels. Farm leaders and government policy-makers manage primarily at the national, sub-national, farm-sector and even international scales but are also concerned with developments at the farm level. Scientists have traditionally pursued a reductionist approach to investigating problems and processes, often to a micro-scale, such as the research plot.

Ideally then, a capability to develop and report indicators at a range of spatial scales is required. However, tradeoffs occur when moving among scales: gains in coverage when reporting at higher spatial scales come with a price; less information is imparted about processes and interactions occurring at lower scales. Conversely, a focus on site-specific detail can obscure the larger picture and make it impossible to track cumulative effects or large-scale or sector-wide trends and impacts. It is therefore important to identify the users of the indicators and the scale(s) at which they require information.

Environmental and economic data on the Canadian environment (including on Canadian agriculture) are captured by numerous agencies and at different scales and spatial units, but have not traditionally been ecologically-based. However, over the past 15 years a number of national-scale ecological maps have been published in Canada that have had application to environmental reporting issues (Wiken 1986, Ecoregions Working Group 1989, Wiken et al. 1993). To meet the challenges put forward to take an ecosystem approach to monitoring and reporting on agricultural sustainability, it was recognized that the concepts and levels of generalization as developed previously were sound but the spatial units defined within the national terrestrial ecosystems framework needed revision, particularly with respect to the agricultural regions of the country.

In 1991, a collaborative project to revise and complete the terrestrial component of the national ecosystems framework was undertaken with a wide range of federal, provincial and territorial stakeholders. The resulting spatial framework consists of multiple, nested levels of ecological generalization with the ability to link to other federal and provincial scientific databases (Ecological Stratification Working Group, 1995). With respect to agriculture, the principles of agro-ecological mapping and development of associated integrated databases in Canada has been summarized by Dumanski et al. (1993). The concept of nested databases serving a range of map scales (or levels of generalization) was used when constructing the design of the relational database for the present national terrestrial ecological framework for Canada.

The broadest level of generalization is the ecozone (Figure 3). Fifteen ecozones have been defined for Canada; agriculture is practised in eight of these. Macroclimate, major vegetation zones and subcontinental scale physiographic formations constitute the definitive components of these major ecosystems. The ecozones are comprised of approximately 200 ecoregions which are based on the properties of regional physiography, surficial geology, climate and vegetation. The ecozone and ecoregion levels of the framework have been depicted on national map coverage at 1:7.5M scale.

Ecoregions are subdivided into ecodistricts based on landform, vegetation and soil development. In the agricultural areas of Canada, previously defined agro-ecological resource areas (Dumanski et al. 1993) were incorporated as much as possible into the national framework as ecodistricts. Ecodistricts are displayed on a separate series of regional map coverages at a scale of 1:3M and represent the level within the framework that is often useful for environmental monitoring, modelling and reporting. Nested within the ecodistricts are the polygons that make up the Soil Landscapes of Canada, a series of 1:1M scale soil maps (Shields et al. 1991). Although not specifically a part of the national ecological framework, the Soil Landscapes of Canada map series provides a suitable aggregate the larger scale products of ecological regionalization (Figure 4).

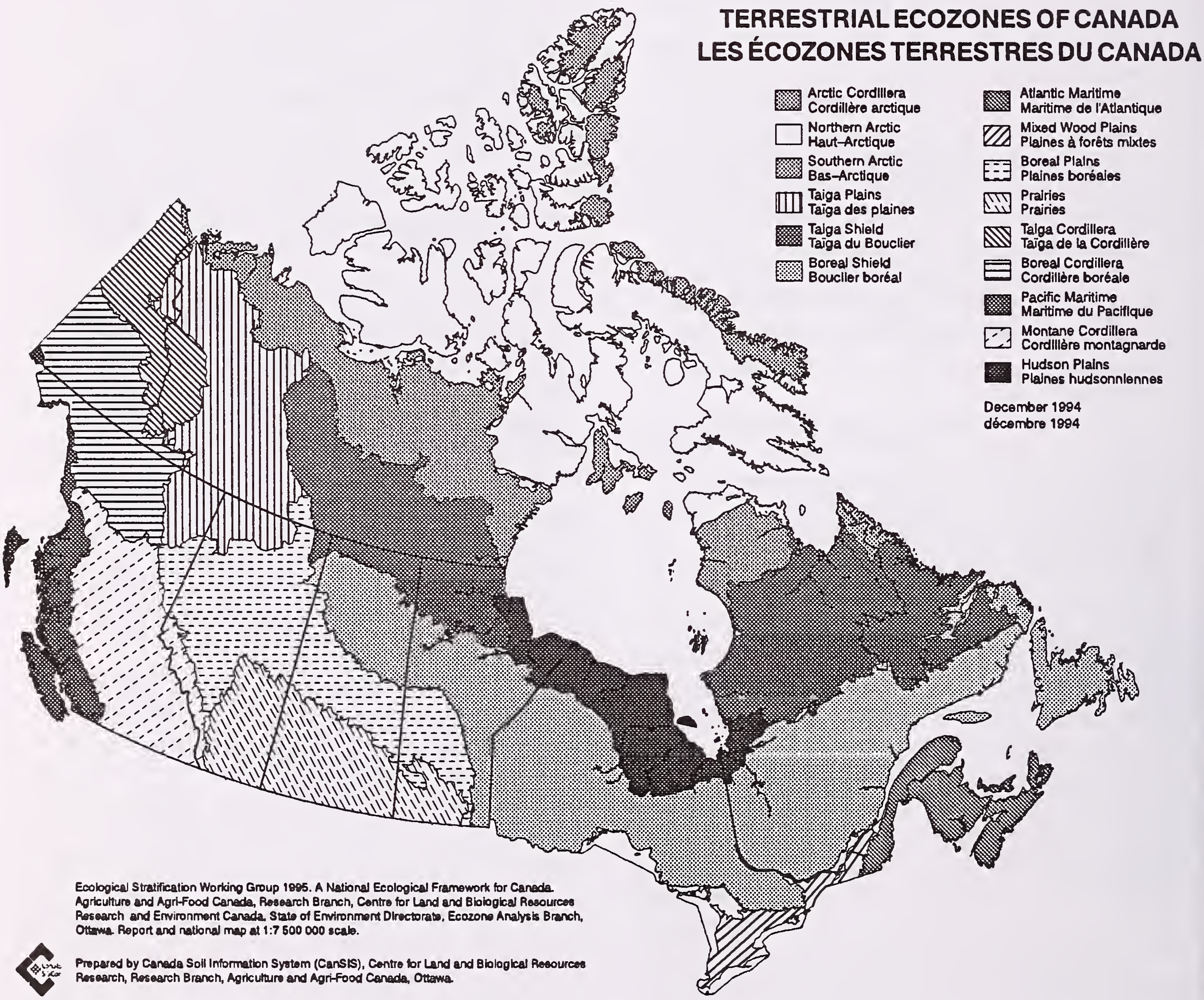


Figure 3. Terrestrial ecozones and ecoregions of Canada.

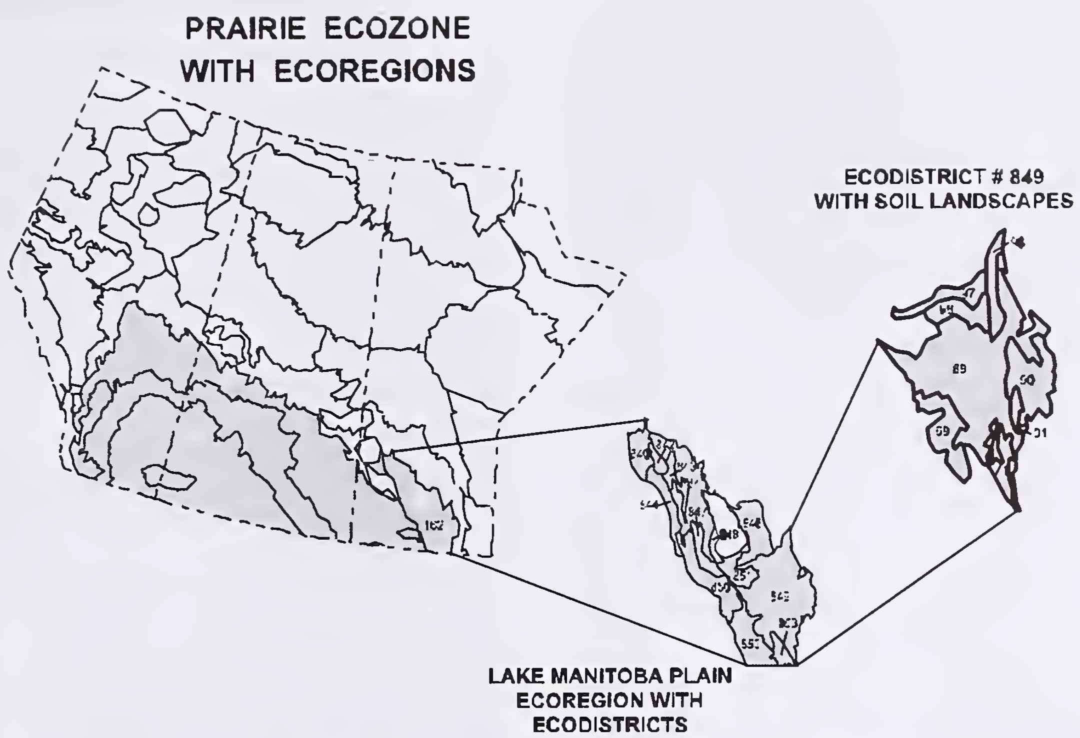


Figure 4. Cartographic nesting of levels of the ecological framework showing the relationship of ecozones, ecoregions and ecodistricts to soil landscape polygons.

Indicators are calculated, measured or modelled at site, field, watershed or regional scales. Because the levels in the framework are nested, results can be generalized, if appropriate, and reported cartographically at either a local (ecodistrict), regional/provincial (ecoregion), national (ecozone) or even international (ecozone) scale. In a similar way, socio-economic data, particularly Census of Agriculture data, may be linked to the environmental data within the framework on a polygon basis at the most appropriate level.

For agri-environmental indicator development, to the extent possible, flexibility is being built into data management and reporting procedures. Ideally, data will be captured at a detailed level (such as the farm level) and then aggregated and reported, as indicators, at whatever scales are most appropriate to specific users such as, for example, on an agro-ecological basis, by watershed, by commodity group, by province or nationally. In some cases, however, data limitations will limit the ability to tabulate and report indicators at many different scales.

3.3 Data Collection and Integration

To develop and validate AEIs, credible, relevant and scientifically rigorous data are required. New opportunities to collect data that are national in scope are few. Furthermore, data required to address environmental problems often must be land-based (i.e. geographically positioned on the earth's surface). Such data collection can be costly and generally beyond the realm of governments in the 1990s. Consequently, there is a need to fully utilize existing datasets as much as possible while also taking advantage of opportunities to fill data gaps as appropriate vehicles and funds permit. In the short term, those indicators making use of available data can be developed now and used to begin reporting on the sustainability of Canadian agriculture.

Partnerships with other stakeholders and agencies are required for the successful development of many of the indicators and the AEI project seeks to build on and integrate past and ongoing research. For example, Agriculture and Agri-Food Canada has gathered detailed data relating to the nature, condition and use of agricultural soil resources and land management practices. Databases such as the Canada Soil Information System (CANSIS) and the Soil Landscapes of Canada database store basic soil data (e.g. soil type, slope class) collected through soil surveys and other mechanisms. The Census of Agriculture operated by Statistics Canada is another key data source for AEIs. Environment Canada collects data related to water quality, habitat availability and other variables. Non-government conservation agencies

collect information on wetlands and wildlife. Provincial departments of agriculture and environment, as well as industry organizations, collect and use data on such variables as land use, cropping practices and farm inputs. Despite these efforts, however, significant data gaps exist that can only be overcome through inter-agency collaboration and focused efforts to collect, standardize, manipulate and integrate data.

Data derived from different sources can be integrated or combined using the spatial approach described in section 3.2. For example, the national Census of Agriculture has tremendous potential for supporting analytical studies on AEIs, but it is limited by its lack of locational accuracy and has traditionally been available only on the basis of politically defined spatial units, such as Enumeration Areas, Census Subdivisions or Crop Reporting Districts. The Soil Landscapes of Canada database stores data on the inherent nature of Canada's agricultural soils (e.g. texture, slope, depth) which, although useful, cannot be used by themselves as indicators. However, when both information sources are integrated, numerous possibilities emerge from an indicator development viewpoint.

To render possible the reporting of indicators derived (in whole or in part) from the census on an agro-ecological basis, census data have been retabulated on the basis of Soil Landscape of Canada (SLC) polygons, which places them into a spatial framework that is more appropriate for developing and reporting some AEIs. Since SLC polygons are themselves nested within ecodistricts, information can be rolled up within the units of the ecological land classification system described earlier for indicator analysis and reporting.

The Census of Agriculture, with its coverage of all farms every 5 years and wide variety of variables, provides a comprehensive picture of the major characteristics of Canada's agricultural industry at a point in time, while also supplying detailed information on small geographic areas not available from other sources. In general, the data can be sub-divided into four sections:

- farm structure, relating to farm size and ownership characteristics;
- crops and land use, detailing the distribution and area of crops, pasture and other land;
- livestock, relating to the type of animals and the size of herd; and
- economics, covering capital investment levels and the dollar value of inputs and sales.

In 1991, in response to the need to track adoption of various management practices by producers, a section was added on land management dealing with tillage practices (conventional, conservation and no-till), summerfallow management and use of conservation structures such as windbreaks, winter cover crops and grassed waterways. To build on this for 1996, an additional question dealing with manure application methods has been added.

Certain questions proposed for inclusion in the 1996 Census of Agriculture were not suited to self-enumerative collection, including questions on quantities of inputs applied (by active ingredient, by crop); frequency and timing of input application; manure storage; and methods used to help decide the type and amount of inputs to apply. Although producers may have been willing and able to answer, some questions took too long to complete and were deemed too burdensome for inclusion in the census. Where a self-enumerative vehicle is inappropriate, other collection options may be considered. The Census of Agriculture provides an excellent list from which to draw a representative sample to conduct follow-on surveys and collect data using other techniques, such as personal interviews or a computer assisted telephone interview (CATI) approach. While more costly to implement, these collection methods are perhaps better suited for collecting this type of environmental data.

Due to the cross-cutting nature of and linkages between the AEIs, many of the variables from the Census of Agriculture and other data sets will contribute to the development of several components of various AEIs. For example, land management variables used to track adoption of soil conservation practices are, in turn, required inputs to other indicators such as Soil Degradation Risk, Indicator of Risk of Water Contamination and Greenhouse Gas Balance. Tracking tillage practices and cropping patterns across Canada is essential to the development of a soil cover indicator component. In other words, the outputs (i.e. results) from one indicator are often inputs to another. It is important to recognize these linkages and the "value added" capability of indicator development.

3.4 Modelling Approaches

For prospective AEIs, the development of a predictive capability is required which links changes in production activities and practices to the environment. Policy development requires information on expected outcomes that can be attributed to government policy initiatives. Both direct and indirect impacts must be identified, measured and assessed against the stated objectives for a policy prior to implementation.

To obtain and use prospective AEIs, an integrated predictive capability is being developed within AAFC. This is limited at the present time to the Prairie grain-livestock economy and to wind and water erosion indicators in the form of the CRAM-EPIC modelling system. This system is a linkage of two separate models: the Canadian Regional Agriculture Model and the Erosion Productivity Impact Calculator. The system is operational and has been used recently to assess the economic and environmental implications that would result from reform of western grain transportation policy as it relates to historically subsidized rail freight rates and to commodity sales pooling programs operated by the Canadian Wheat Board. Examples of outputs from the CRAM/EPIC model are presented in section 4.2.

The overall objective is to develop a predictive capability for all key AEIs. The analytical capability will eventually be extended to also investigate longer term sustainability questions relating anticipated changes in resource quality back to production and agricultural income projections.

3.5 Indicators Identified for Development

The process of identifying appropriate AEIs for Canadian agriculture has been an iterative one characterized by ongoing discussions between researchers, analysts, policy-makers, national and regional farm organizations and stakeholder groups such as environmental organizations.

In the initial phase of the work, 49 potential indicators were identified by AAFC to provide a basis for discussion. These indicators were clustered around a range of agri-environmental issues. Through an interactive consultative process spanning an 18 month period, the potential indicators were reviewed, ranked and ultimately integrated/combined, and others dropped, to arrive at a core set of six performance indicators and their components. To date, two national consultation workshops have been held with stakeholder and client groups to garner input into the design of the project and the selection of indicators (McRae and Lombardi, 1994; McRae, 1995). A multi-stakeholder advisory committee is planned to provide a mechanism for ongoing discussion and input into the indicator project.

Each of the AEIs, illustrated in Figure 5, is linked to a key agri-environmental issue and a corresponding performance objective. The comprehensive indicators are composed of several attributes or components (some of which may, by themselves, be considered AEIs) which are, in turn, based on the integration of specific data. It must be emphasized that the core set of indicators does not constitute a comprehensive set as several important issues, such as compaction of soils, are not presently covered.

The indicators are at various stages of development. Preliminary results for several are presented in Section 4.

4.0 SELECTED EXAMPLES OF AGRI-ENVIRONMENTAL INDICATORS

This section provides examples of some of the AEIs currently being developed. These examples are for illustration purposes and, with the exception of soil erosion risk, erosion control practices and tillage practices, have not been peer reviewed or published in the scientific literature. Consequently, they should not be reproduced and reported or referenced elsewhere as indicative of actual trends and conditions in Canadian agriculture.

4.1 Farm Resource Management -- Soil Cover and Management Component

The indicator component is comprised of two related sub-components: trends in farm-level adoption of selected soil conservation practices and trends in area of agricultural land under various classes (low, medium and high) of soil cover.

Table 1 and Figure 6 illustrate two aspects of land management derived from the land management module of the 1991 Census of Agriculture - use of selected erosion control practices and tillage practices used to prepare land for seeding. Extent of adoption of selected soil conservation practices pro-

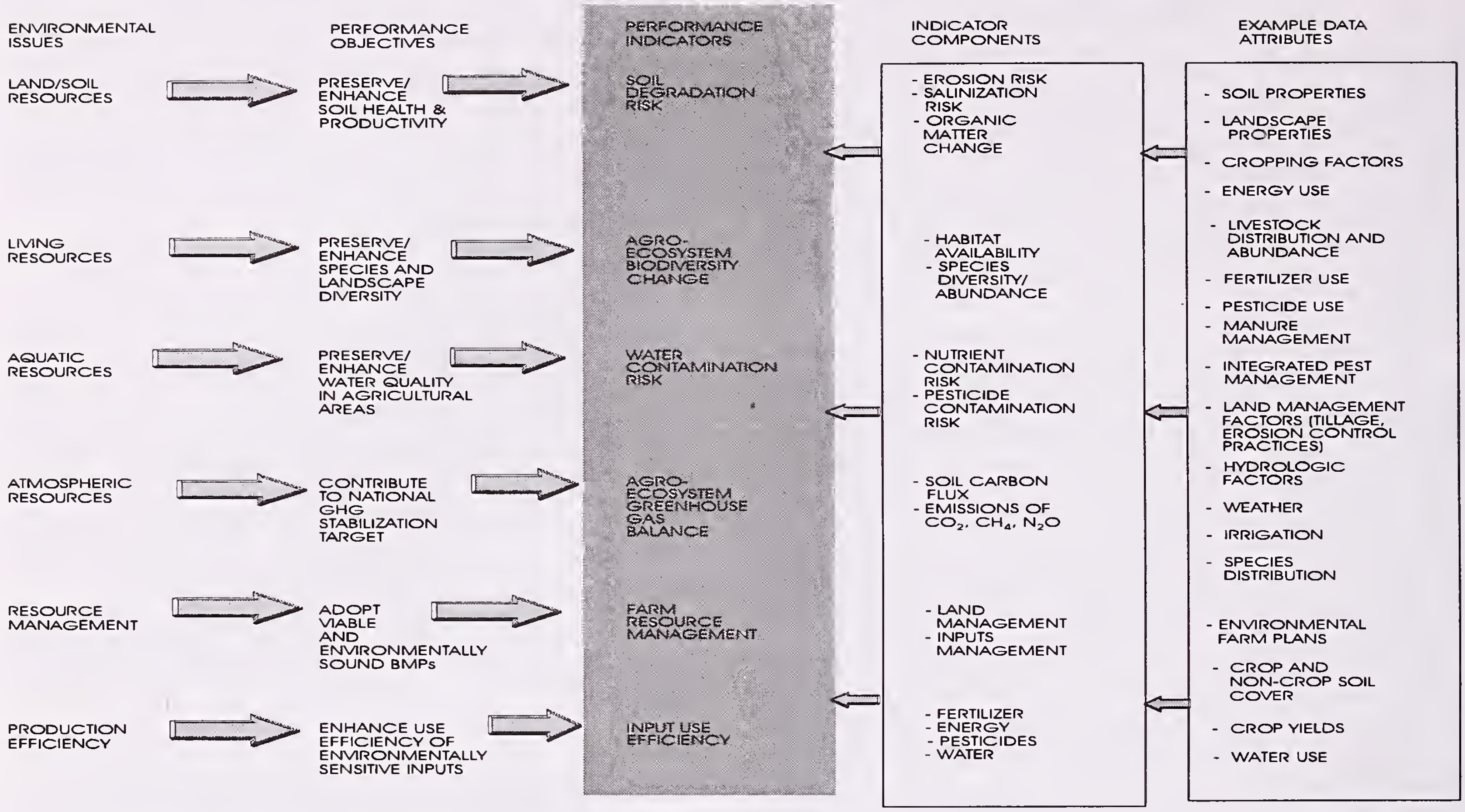


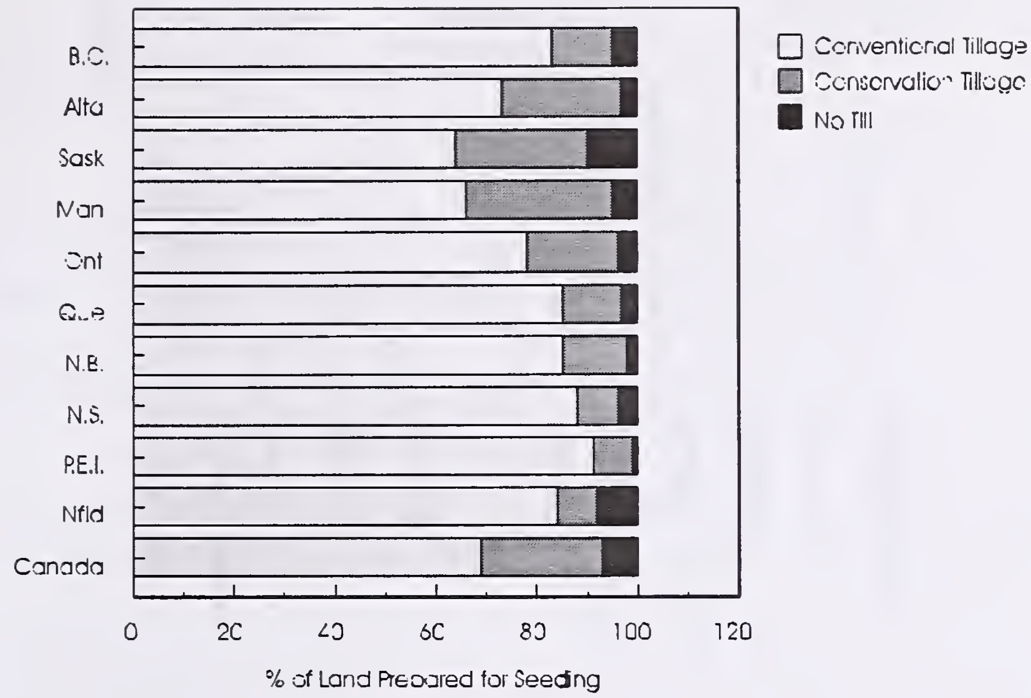
Figure 5. Linkages between agri-environmental issues, objectives, indicators and supporting data.

vides an indication of how soil erosion and land degradation issues are being addressed across Canada (Trant, 1993) and perhaps also of the need for erosion control. Not all agricultural lands require erosion control and some practices are only applicable in some regions and not in others (e.g. strip cropping in the prairie region). Since 1991 was the first time such questions were asked through the census, these data effectively constitute a baseline against which future census data will be compared.

TABLE 1. Erosion control practices in Canada, 1991 (percent of farmers reporting).

Province	Forages	Winter cover crops	Grassed waterways	Strip-cropping	Contour cultivation	Wind breaks
British Columbia	23	11	10	2	5	13
Alberta	43	7	17	10	11	29
Saskatchewan	22	6	12	21	18	35
Manitoba	35	7	13	5	13	37
Ontario	60	20	15	4	7	21
Quebec	52	4	4	3	4	8
New Brunswick	44	10	9	5	8	8
Nova Scotia	34	12	8	3	8	7
Newfoundland	37	7	4	1	7	12
Prince Edward Island	72	9	11	4	10	16
Canada	42	10	13	9	10	15

Source: Dumanski et al. 1994.



Source: Dumanski et. al., 1991

Figure 6. Tillage practices used to prepare land for seeding in Canada, 1991.

Together and in combination with other census data (not shown) this information reveals that, in general, producers are taking concrete steps to address soil degradation issues:

- the use of erosion control and seedbed cultivation practices varies considerably by region of Canada;
- farm operators with 85% of seeded area used some form of soil erosion control or soil conservation practice. Conversely, four and one-half million hectares (15%) had no erosion control applied and were not tilled using a conservation technique, although not all of these lands require erosion control; and
- arms with the most potentially erosive crops are the most frequent users of four out of six erosion control practices.

Changes in soil cover on agricultural land between 1981 and 1991 are illustrated in Figure 7. Land under high cover is at less risk of soil erosion and degradation than land under low cover. The indicator reflects the amount of soil cover provided based on prevailing cropping and tillage practices.

Soil cover is estimated based on the principles outlined in the revised universal soil loss equation, as follows: individual crop types are cross-referenced to the tillage practices under which they are grown and the various potential combinations are classified into three classes of soil cover -- low, medium and high. Assignment of each combination to a cover classification is based on expert opinion and research results. For the 1981 year, it is assumed that all tillage is conventional. To illustrate: grain corn under conventional tillage is classified as a low cover crop, under conservation tillage as a medium cover crop and under no-till as a high cover crop. Silage corn is considered a low cover crop regardless of the tillage practice used. Areas under various cover classes are computed and summed. The indicator is presently calculated nationally and at the provincial level and will eventually be extended to the ecodistrict level.

Based on the analysis presented in Figure 7 and on related data, the following preliminary trends are apparent for the period between 1981 and 1991:

- nationally, cropland as a proportion of farmland has increased from 47% to 49%, an increase of about 2.5 million hectares;
- the portion of farmland in summerfallow and in pasture has decreased from 15% to 12% and 31% to 30% respectively;
- the proportion of cultivated land (annual crops) with low cover and medium cover has decreased from 34% to 22% and 53% to 46% respectively; and

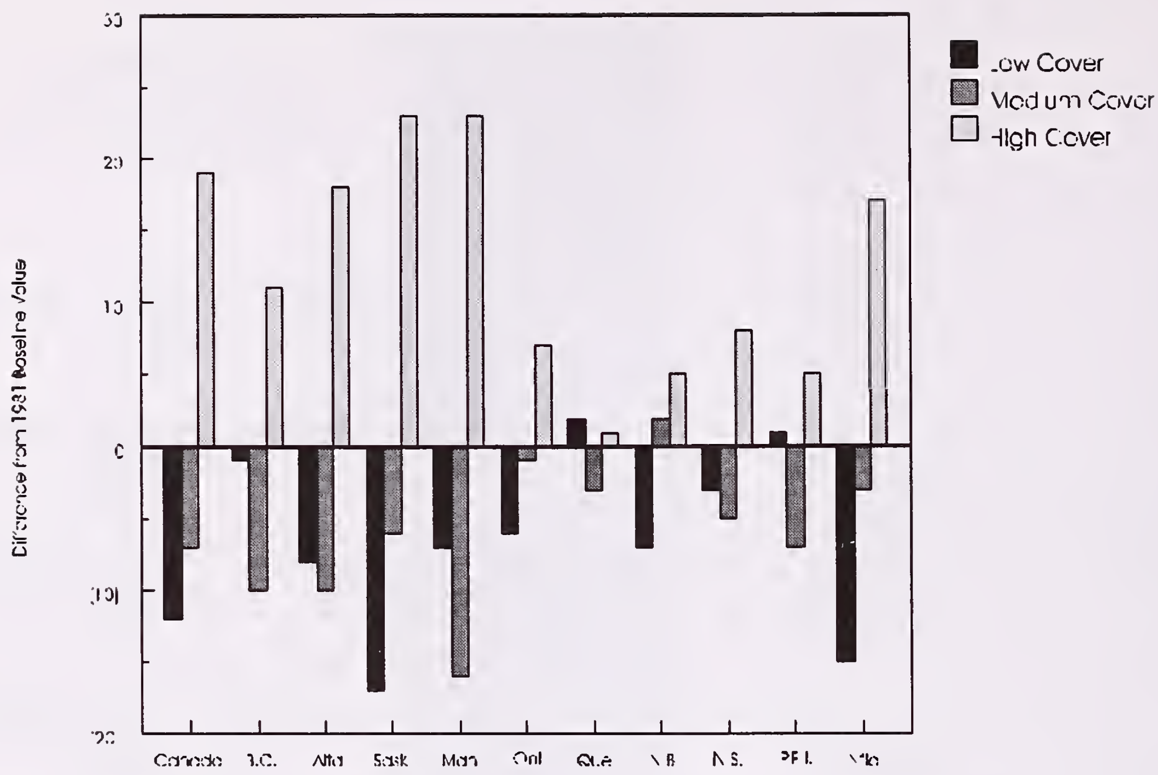


Figure 7. Soil cover change between 1981 and 1991.

- the proportion of cultivated land with high cover has increased from 13% to 32%.

From a soil quality perspective, these trends are generally encouraging as the risk of erosion is expected to have declined between 1981 and 1991 due to increases in cover. Increased soil cover also benefits biodiversity and recycles soil carbon, thus limiting carbon dioxide emissions. Nationally, the increase in soil cover is attributed to the adoption of land tillage practices that maintain residue on the surface. However, shifts in cropping patterns from crops with higher residue levels to those with lower residue, such as from grain corn to soybeans or from wheat to canola, partially offset these gains. (Curran et al. 1995).

4.2 Soil Degradation Risk -- Erosion Component

The Soil Degradation Risk indicator includes erosion, salinity and soil organic matter components. Results are presented here for the erosion component only with a complete analysis of all components reported in Acton and Gregorich (1995).

Soil erosion is an issue that has received considerable public attention in Canada. The issue was publicized nationally by Sparrow (1984) and substantial efforts have been made since then to address erosion concerns (e.g. National Soil Conservation Program, Land Management Assistance Program, Permanent Cover Program, Green Plan, etc.). Producers have voluntarily moved to adopt farm management practices to improve land management, as illustrated in Table 1 and Figure 6 above.

An indicator has been developed to evaluate progress in reducing erosion risks and to identify areas which remain at higher relative risk of erosion. The indicator is calculated at the Soil Landscapes of Canada polygon level using land use and management data coupled with the corresponding soil and slope information. The Universal Soil Loss Equation and the Wind Erosion Equation are used to integrate the required data and to calculate the indicator components. Although calculated in tonnes/hectare/year, the erosion indicator is reported in risk classes due to the generalization of the erosion models at such broad scales. A total of five classes are reported, ranging from low, moderate, tolerable, high and

Table 2. Reduction in actual water erosion risk per hectare from 1981 - 1991.

Province	Cultivated land in 1991 (million ha)	Erosion reduction per hectare (%) Resulting from cropping practice	Resulting from tillage practice	Total
British Columbia	0.61	7	10	17
Alberta	11.06	5	8	13
Saskatchewan	19.17	5	3	8
Manitoba	5.06	6	9	15
Ontario	3.48	10	11	21
Quebec	1.65	3	3	6
New Brunswick	0.12	2	4	6
Prince Edward Island	0.16	- 9	3	- 6
Nova Scotia	0.11	-3	3	0
Canada	41.42	5	6	11

SOURCE: Wall et. al., 1995.

severe. Tolerable rates of erosion are those that have been shown to permit the long term sustainability of crop production.

Table 2 and Figure 8 report changes in the risk of water and wind erosion respectively from 1981 to 1991. Water erosion is reported nationally while wind erosion is primarily of concern in the prairie region. For both water and wind erosion, the indicators reveal that important progress has been made in reducing erosion risk. Figure 9 provides a spatial overview of water erosion risk changes on the Canadian prairies between 1981 and 1991 and demonstrates how this analysis can be used to direct soil conservation efforts at high-risk areas.

As mentioned in Section 3.4, a prospective capability has also been developed for the soil erosion indicator component for the prairie region. A modelling system integrating economic and environmental variables is being developed based on the Canadian Regional Agricultural Model (CRAM) and the Erosion Productivity Impact Calculator (EPIC). This modelling system is described in detail in Agriculture

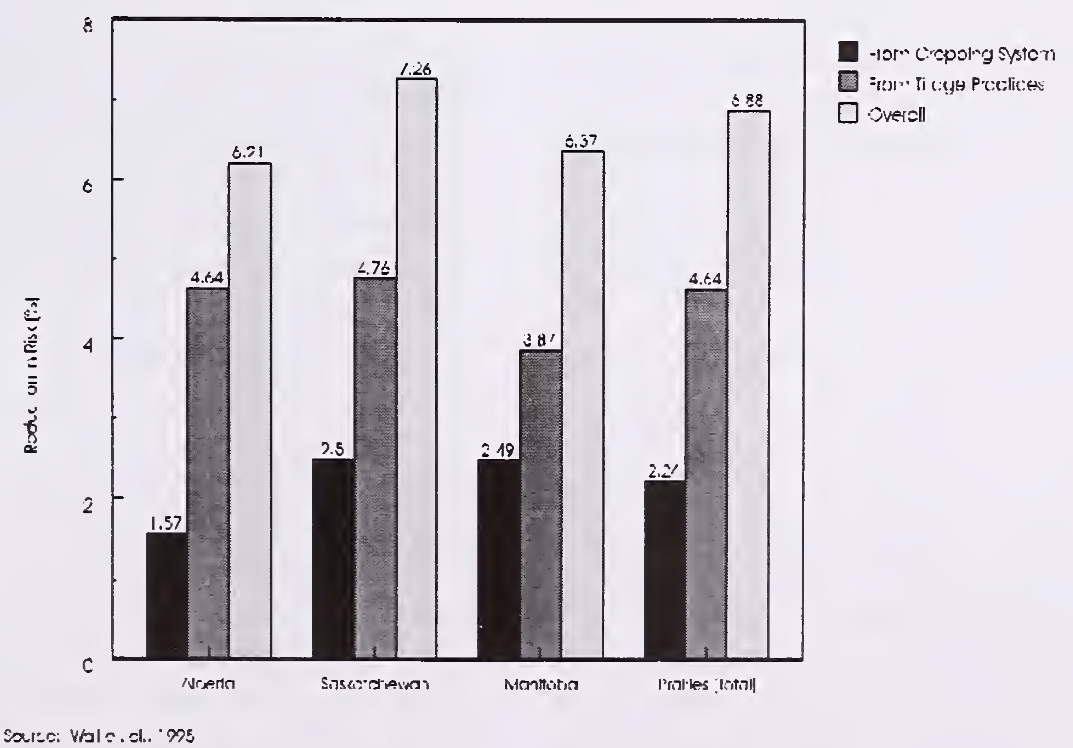


Figure 8. Reduction in the risk of wind erosion in the Prairie Provinces between 1981 and 1991.

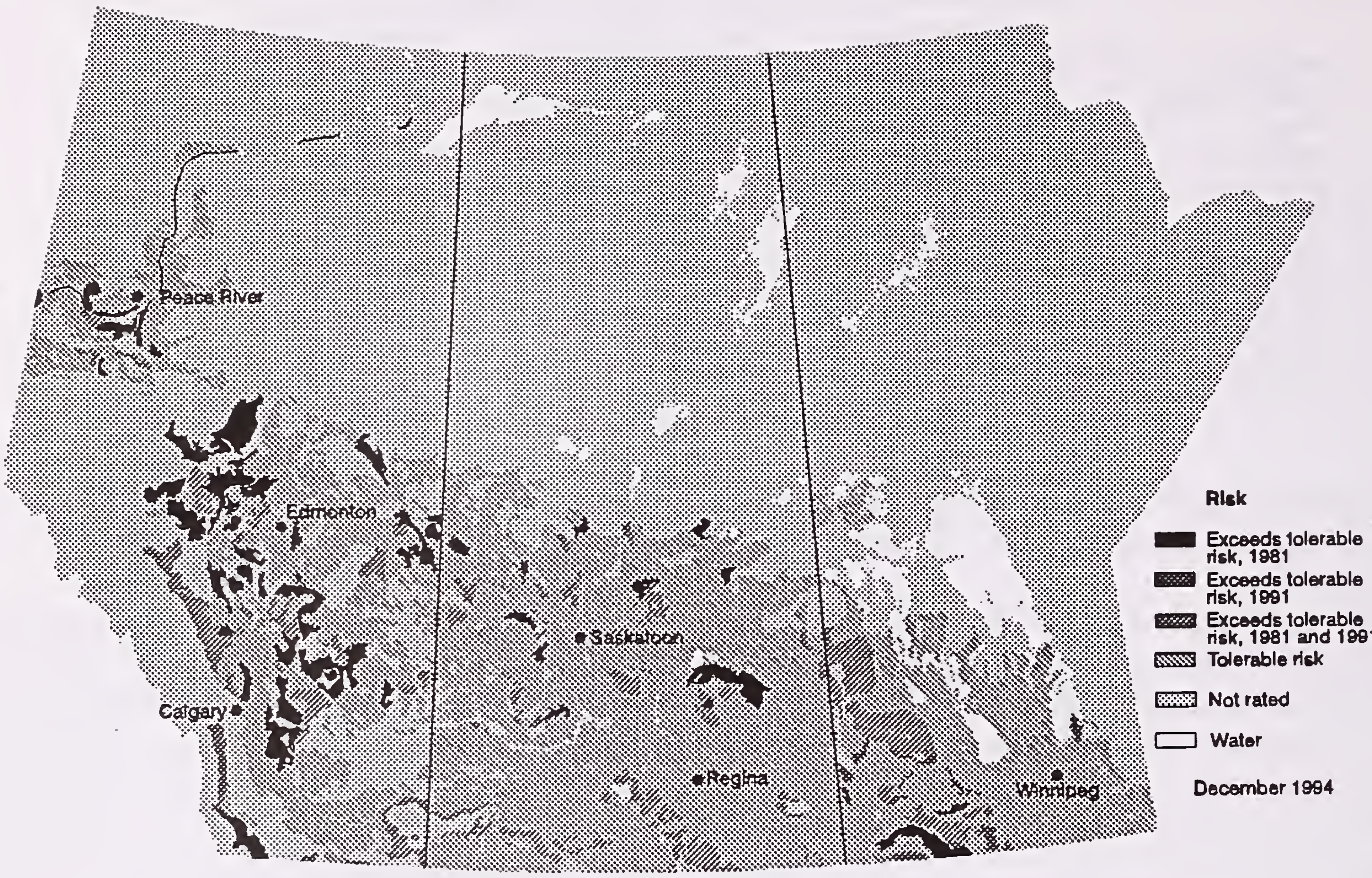


Figure 9. Changes in the risk of water erosion in the Prairie Provinces between 1981 and 1991.

Canada (1993a, 1993b, 1994, 1995a, 1995b). Similar to the work on the retrospective soil erosion risk indicator, the CRAM-EPIC modelling system currently has the capacity to link wind and water soil erosion rates on the Prairies to farm management practices which change in response to policies, markets, technology or some combination.

To predict erosion rates, comparable methodologies are being employed. EPIC is the environmental component which estimates field level yields and erosion rates based on various agricultural and environmental variables. EPIC uses the Modified Universal Soil Loss Equation to predict water erosions rates and the Wind Erosion Continuous Simulation to predict wind erosion. Simulations were carried at the 1:1 million scale based on dominant and sub-dominant soils in Soil Landscape Polygons (CanSIS Landscape Database). Based on a stratified sample and 22,000 simulation runs, summary response functions called metamodels were constructed. Producer response in the form of crop/rotation/tillage choices as predicted by CRAM are passed to the metamodels to determine how changes in farm management decisions would affect soil erosion rates.

This system provides the integrated information policy makers need in order to assess both the environmental and economic consequences of proposed actions, identifies tradeoffs and can be used to assess mitigation requirements. This system was used recently to provide a quantitative assessment of the implications of eliminating the Western Grain Transportation Act (WGTA) freight subsidy for Prairie grains and oilseeds and reforming the Canadian Wheat Board pooling regime. The CRAM model predicted the following land use changes: (1) a shift from barley and wheat to higher valued, lower volume oilseeds and specialty crops, (2) more summerfallow in some regions, and (3) some land shifting from grain production to forage in other regions. A priori, the first two adjustments would be expected to increase erosion rates while the third one would reduce erosion rates.

The quantitative implications of these policy changes for water erosion rates are as follows. In the western Prairies a movement towards oilseeds and greater use of summerfallow would lead to a small increase (0 to 3%) in water erosion rates. In the eastern Prairies, where the impact of the policy change would be much larger, the net impact of shifting land to forage from grains would reduce the aggregate rate of water erosion. Several areas of the central prairie region would experience no significant change in erosion rates. A similar pattern was found for wind erosion rates (B. Junkins, pers. comm.).

From a policy perspective, the announced changes to the WGTA would not have a significant impact on soil erosion by water for the prairies as a whole. However, information on the predicted erosion rate changes within the prairie region could be combined with the retrospective erosion risk indicator to assess whether those regions identified at high to severe risk coincide with those regions where erosion rate increases are predicted. Efforts to mitigate could be targeted in those areas where a high risk situation would be exacerbated.

4.3 Indicator of Risk of Water Contamination (IROWC) -- Nutrient Component

This indicator is being designed to assess the risk of water contamination from primary agriculture, which has emerged as a key agri-environmental issue. Risk of contamination is a function of contaminant properties, environmental conditions and specific land use and management practices (e.g. crops grown, inputs used, etc.), thus the indicator must be capable of integrating data on diverse factors in a meaningful way.

The methodology being pursued is to develop the indicator using a partial budgeting approach which will estimate the concentration or amount of potential contaminants available as a result of agricultural activities in comparison to tolerable concentrations as defined by various water quality standards and objectives (i.e. a ratio of the potential contaminant concentration to the allowable contaminant concentration) (Macdonald and Spaling, 1995b). The focus of the IROWC at this time is on nutrients and pesticides.

This approach is preferred to more conventional water quality monitoring approaches because it is directly linked to agriculture as a source of contamination (thus eliminating problems of interpretation due to other potential contaminant sources) and is not dependent on the availability of comprehensive water quality monitoring data, which are expensive to collect in a country as large as Canada. Water quality data will, however, be essential for verifying and calibrating the indicator.

Scale determines the potential level of detail and also the factors which can be included in the indicator. The IROWC will be calculated at the ecodistrict level across Canada and also in selected regions at a more detailed scale. The regional studies will serve to verify that the national (ecodistrict) level indicator correlates reasonably well with more localized conditions and they will provide information for interpreting the national level indicator. Development of the IROWC is in the preliminary stages. A concept paper and a draft methodology paper have been prepared (Macdonald and Spaling, 1995a & 1995b) and the methodology will undergo further development.

A partial illustration of the IROWC is provided in Figure 10. The figure shows changes in the relative potential contaminant concentration for nitrogen in Ontario between 1981 and 1991 at the ecodistrict level (based on levels harvested in the crop) and is the numerator of the full IROWC ratio described earlier. The results are reported in units of mg/l or ppm with the range going from a decrease of five or less to an increase of five or more. In general, these results are quite encouraging for much of the province, showing no change or a slight decline. The greatest increase is indicated in the ecodistrict which occupies north Middlesex and the western portion of Huron Counties. In addition, there is some indication of an increase in Eastern Ontario, Essex and Lambton Counties and the fringe area. The map illustrates that this type of calculation can indicate some changes that are potentially of the same order of magnitude as the drinking water standard of 10 ppm for nitrate (Macdonald and Spaling, 1995b).

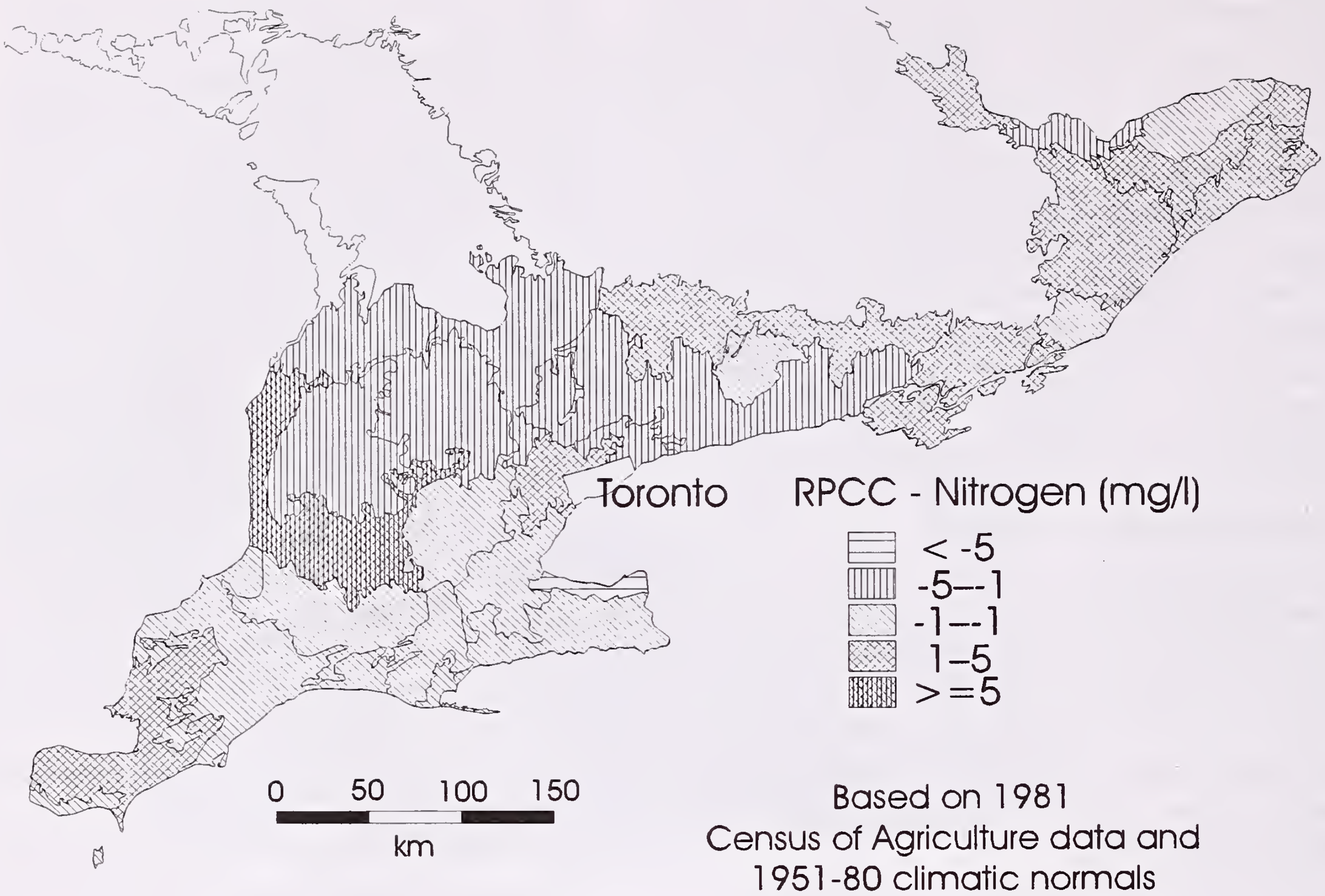


Figure 10. Change in the relative potential contaminant concentration in southern Ontario (nitrogen, 1981-1991).

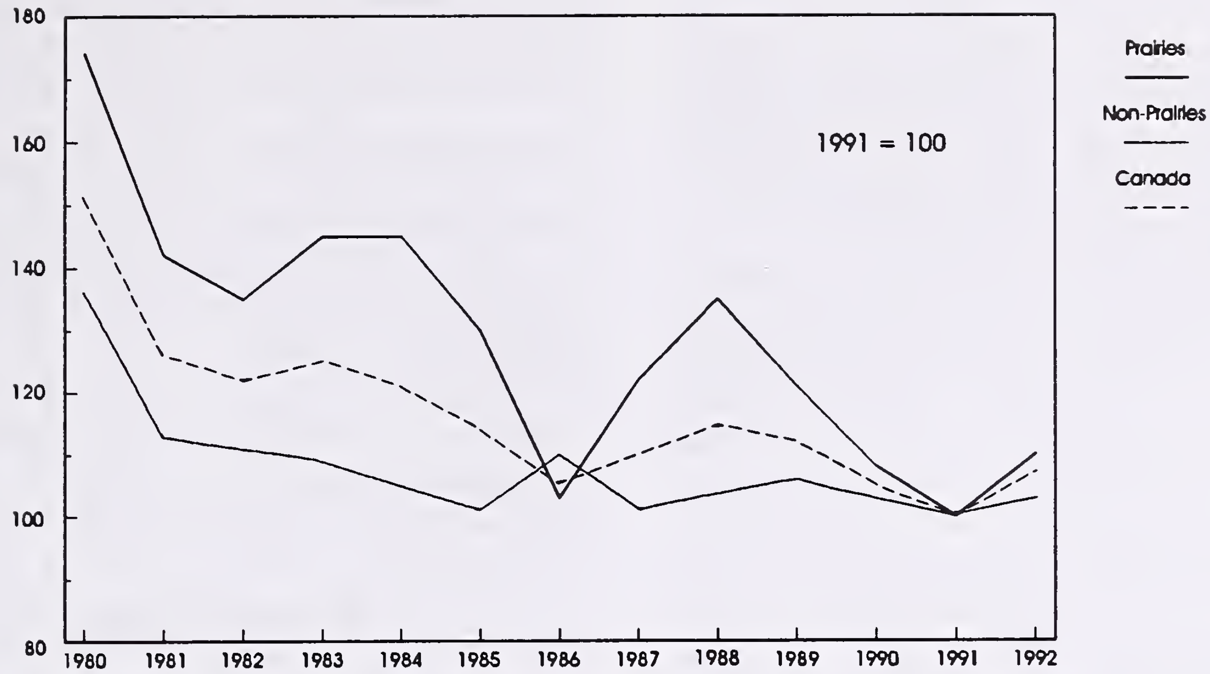
4.4 Input Use Efficiency — Energy Component

This indicator provides a measure of the use efficiency (input/output ratio) of chemical inputs of fertilizers, pesticides and energy (farm fuel and electricity) used in Canadian agriculture over time. The trends in this measure can provide an indirect perspective on the potential direction of environmental risks.

Quantities of fertilizer, pesticide and energy inputs are obtained on an annual basis for each input item. Physical quantity data and implicit quantity data (derived from expenditure data in constant prices) are used. These quantities are then aggregated and indexed to a base year using corresponding price and share weights for fertilizers, pesticides and energy respectively. Annual indexes for aggregate output were also developed in the same manner for crop and total output respectively.

The aggregate input index (numerator) is then divided by aggregate crop output index (denominator) to arrive at the indicator of input use efficiency for fertilizers and pesticides as these are, by and large, applied to crop production. For energy, the aggregate input use index is divided by the total output index (i.e. crop and livestock output) since energy is used for both crops and livestock. The reverse of this process gives the partial productivity index for the respective inputs.

The indicator can be calculated at various spatial scales: national, eastern Canada, western Canada, prairie Canada and non-prairie Canada. The dividing line for the eastern and western regions of the country is the Ontario/Manitoba border. On a temporal scale, the indexes are available for the 1961 to 1992 period but the present analysis uses 1980 as the baseline year. Figure 11 illustrates a preliminary calculation of the indicator for energy. Trends from 1980



Source: Narayanan, 1995.

Figure 11. Input efficiency for energy inputs, 1980-1992.

are indexed using 1991 set at 100. A decrease in the slope of the line indicates that less input is being used per unit of output; an increase denotes the opposite.

For on-farm energy use, efficiency has increased both nationally and regionally. This has positive implications for climate change and local air pollution issues. Factors responsible for the improvement in energy use efficiency include improved genetics & plant productivity, reduced tillage, improved fuel efficiency in farm equipment and enhanced farm building insulation.

The input efficiency indicator, while useful in demonstrating aggregate trends over time, has limitations. The use of implicit quantity data introduces some uncertainty in the trends observed, although implicit quantity data do correlate reasonably well with actual use data. More importantly, the indicator does not distinguish between types of inputs (eg. different types of nutrients and pesticides) and cannot be calculated by crop. For these reasons, this indicator is best interpreted in association with information derived from other related indicators (Narayanan, 1995).

4.5 Agroecosystem Greenhouse Gas Balance — Carbon Dioxide Component

This indicator will estimate sources and sinks for the three principal greenhouse gases emitted from agriculture and express the net balance in carbon dioxide equivalent units. Carbon dioxide, nitrous oxide and methane are the most important greenhouse gases (GHG) emitted by agricultural sources. Agriculture generates carbon dioxide through the combustion of fossil fuel for farming operations and the production of various inputs (nitrogen fertilizers, pesticides, etc.).

Agricultural soils can act both as a source or a sink of carbon (C). The C content in agricultural soils is a function of the original C content, time elapsed since cultivation began, and crop and soil management. After conversion to agriculture, soil C takes between 20 and 50 years to stabilize to a new equilibrium level. Long-term experiments have shown that soils under conventional tillage or fallow stabilize at a lower C content that those under no-tillage or continuous cropping systems. In order to estimate the net gain or

loss of soil C in Canadian agroecosystems, it is therefore necessary to determine, for a given baseline year, the fraction of agricultural soils that have reached their equilibrium of C content (assuming negligible losses by erosion) and the rate of change for those soils that are not in equilibrium. Small quantities of carbon are also stored in farm woodlots.

Nitrous oxide is produced in soils as a by-product of nitrification and denitrification processes. A fraction of this nitrous oxide is released at the soil surface and contributes to the increase in the atmospheric nitrous oxide concentration. The total amount of nitrous oxide emitted from soils is the summation of a background component (resulting from the natural cycling of nitrogen), a manure component (for soils receiving manure) and a nitrogen fertilizer component (for soils receiving nitrogen fertilizers). Manure also generates nitrous oxide during storage in quantities that vary depending on the type of storage practice and the duration of the storage period. Other agricultural sources of nitrous oxide are combustion of fossil fuels and biomass burning. The sources of methane in Canadian agroecosystems are ruminants, animal wastes, wet areas (within agricultural land) and combustion of fossil fuel.

The sources and sinks of GHG in agroecosystems are reasonably well known but the magnitude of the various fluxes is less certain. However, significant research efforts are currently being made to reduce this uncertainty. Another important aspect of the estimation of the contribution of Canadian agroecosystems to GHG is the aggregation of the individual sources and sinks. Emissions of GHG vary greatly depending on various factors related to soil, climate and management practices, which are characterized by high spatial variability. Typical combinations of these factors are being used to represent Canadian conditions.

Partial results of the work on this indicator are shown in Table 3 for carbon dioxide. The calculations estimate the net release of carbon dioxide from agricultural sources in 1991 to have been 20.8 million tonnes, approximately 4.4 percent of the estimated net total for Canada. On-farm fuel use, soil carbon loss and nitrogen fertilizer manufacture accounted for, respectively, 50%, 35% and 15% of the total. Net releases increased slightly from 1986 to 1991 (P. Rochette, pers. comm.).

Research to quantify the net sources and sinks of methane and nitrous oxide is in progress with a view to ultimately estimating a comprehensive net GHG balance for Canadian agriculture.

5.0 CONCLUSIONS

Concerns about environmental issues and the need for sustainable management of ecosystems are placing demands on both the generators and users of environmental information. To be useful to decision-makers, information must be delivered in a useable and understandable form. Environmental indicators are an important tool for delivering information into the decision-making process.

The development of environmental indicators is closely linked to environmental monitoring and assessment. Methods for collecting data and interpreting their significance are essential for the development of environmental indicators. Monitoring efforts need to consider the causes and nature environmental change, coupled with use of objectives and reference thresholds for interpreting the significance of observed trends.

Efforts are underway within Agriculture and Agri-Food Canada to develop agri-environmental indicators for Canadian agriculture. Agriculture's environmental agenda has evolved from its historic focus on

Table 3. Estimated net emissions of carbon dioxide from Canadian agroecosystems (million tonnes).

Year	On-farm fuel use	Soil carbon flux	N-fertilizer manufacture	Total
1986	9.2	7.3	3.2	19.7
1991	10.4	7.2	3.2	20.8

Source: Smith et al., 1995; J. Liu, pers. comm.; Jaques, 1992; Jackson, 1992.

on-farm resource concerns to also encompass off-farm concerns associated with impacts on public environmental goods (e.g. water quality, biodiversity). As a result, the agri-environmental policy process has expanded and become more complex, with competing sets of objectives frequently characterized by inherent tradeoffs. To manage this increasingly complex agenda, decision-makers and stakeholders require information to inform their discussions and on which to base and evaluate the decisions taken.

If the efforts expended to develop indicators are to yield the desired results, both the process as well as the substance of indicator development must be considered carefully. The Canadian experience to date in this area suggests that three criteria for agri-environmental indicators stand out above all others: policy relevance, scientific defensibility and regional sensitivity.

To ensure policy relevance, indicators must address critical issues, identify areas and resources at higher relative risk and provide information on whether or not policy objectives associated with the issues are being attained. Both a retrospective and prospective capability is required for indicators to fully address policy assessment and design needs.

The identification of issues and subsequent selection of indicators should be based on a consultative process in which all potentially affected parties can participate. Developed in isolation by an un-representative group or groups (for example, by scientists or bureaucrats), the indicators that emerge run a strong risk of not responding to the needs and concerns of all parties. Identification of appropriate indicators is therefore a process that integrates both scientific as well as policy considerations.

To deliver information to as many users as possible and to ensure regional sensitivity, a capability to report indicators at a range of spatial scales is required. These can be based on ecological units, political units, or both. Finally, a scientific capability is essential for indicator development. Indicators based on poor science will not serve the policy process well and could, in fact, lead to erroneous decisions requiring costly remedial action or loss of agricultural productivity.

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Selecting and Testing Indicators of Forest Health

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Abstract.—Forest Health Monitoring is a long-term, national program to monitor and report on the status, changes, and trends in the condition of forest ecosystems in the 48 contiguous states, Alaska, and Hawaii. The U.S. EPA and the U.S. Department of Agriculture Forest Service share leadership of the program. Extensive interagency participation is a key feature of the FHM program. Six federal agencies, 18 state forestry or agricultural agencies, the National Association of State Foresters, and 13 universities participate in various aspects of program management, training, plot establishment, data collection and analysis, quality assurance and control, assessment, and reporting.

FHM also collaborates with other national long-term monitoring programs that assess and periodically report on the condition of ecological resources in the United States. One such program called the Environmental Monitoring and Assessment Program (EMAP), focuses on both aquatic and terrestrial ecosystems.

Forest health is that condition of a forest that sustains its complexity and diversity while providing for human needs. The steps that must be taken to adequately assess the health of the forest resource are: (1) develop a conceptual approach or model that provides a framework for monitoring, (2) identify societal values and assessment endpoints of concern, (3) select and test an ecologically meaningful set of indicators that addresses the societal values and assessment endpoints of concern, (4) establish baseline data using indicators that meet certain indicator performance criteria, (5) develop standards to compare current conditions against, and (6) initiate a monitoring program to assess current condition, and detect changes and trends in ecological condition.

A set of ecological indicators has been selected and tested by FHM over the past four years. The indicators cover a broad range of forest ecosystem components and processes and help answer assessment questions related to forest productivity and sustainability, biodiversity and wildlife habitat, aesthetics, and the forest environment. A methodical approach for determining the performance characteristics of indicators has been developed by FHM. Indicator measurements are collected using a national systematic sampling grid and 1-hectare ground plots. Rigorous quality assurance and quality control procedures are used to provide data of known and acceptable quality. Indicator performance standards have been developed for evaluating the utility of the indicator in a national monitoring program.

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OVERVIEW OF FOREST HEALTH MONITORING

The U.S. EPA initiated a multiagency program to determine the current status and future trends in the nation's ecological resources. The Environmental Monitoring and Assessment Program (EMAP) focuses on broad resource groups such as inland surface waters, estuaries, arid lands, agroecosystems,

and forests. During a similar time period, the U.S. Department of Agriculture Forest Service was conducting the National Vegetation Survey, a part of the Forest Response Project. Recognizing similar goals, the EMAP-Forests group and the Forest Service's National Vegetation Survey joined forces to create the multiagency effort known as Forest Health Monitoring (FHM). The FHM program is jointly managed and largely funded by the U.S. Department of Agriculture Forest Service and the U.S. EPA, in cooperation with other program participants. FHM partners provide additional financial and personnel support and include participating State Forestry agencies, the U.S. Department of Interior (USDI) Bureau of Land Management, the Tennessee Valley Authority, and the USDA Soil Conservation Service. Other cooperators include universities, and three USDI agencies - U.S. Fish and Wildlife Service, U.S. Geological Survey, and the National Park Service. The National Association of State Foresters provides essential program support, guidance, and assistance.

The FHM program has selected key indicators of forest condition and stress that have been tested in various research studies over the past four years. A methodical approach has been developed for assessing the performance characteristics of these indicators. This paper discussed the approach FHM has used in selecting and testing its indicators.

DEFINITIONS, CONCEPTS, AND TERMINOLOGY

FHM has selected a set of indicators that addresses important societal values and relates quantitatively or qualitatively (in some cases) to key ecological assessment endpoints.

A value is a desired characteristic of the environment. Although the term value has been referred to as environmental value and societal value in various FHM documents (Alexander and Barnard, 1992; Palmer et al., 1992; Lewis and Conkling, 1994) only societal value will be used throughout this document. EMAP and FHM have agreed on three major societal values: biological integrity, consumptive use, and non-consumptive use. Biological integrity is defined as: the ability to support and maintain a balanced, integrated, adaptive community with a biological diversity, composition, and functional organization comparable to those of natural systems (reference sites) of the region (Frey, 1977; Karr and Dudley, 1981). A consumptive use value is one that is derived from the worth of environmental goods or services based on their ability to be extracted (Bishop and Hoag, 1993). "Worth" as used here is not necessarily intended to denote monetary value of a resource. Consumptive use values entail extracting something from an ecological resource in order to produce a tangible product of worth to humans. Examples include fishing, hunting, timber harvesting, and agricultural production. A non-consumptive use value is one that is derived from the worth of environmental goods or services that are not extracted, or are only passively exploited, by those holding value for this good or service (Bishop and Hoag, 1993; Freeman, 1993). Here again, "worth" is not intended to denote only the monetary value of a resource. Non-consumptive use values consist of all values not derived via extractive activities. A few examples include hiking, birdwatching, as well as "non-use" or "passive-use" activities associated with the mere existence of natural assets, often referred to as "existence values". Existence values are values based on bequests or endowments to future generations; motives other than personal enjoyment of resources or products that are derived from these resources (e.g., altruism, stewardship, moral convictions) (Scodari, 1990). Also, amenity or aesthetic values are examples of non-consumptive use values (e.g., scenic, spiritual, cultural, historical).

In the FHM program the next hierarchy below the three major societal values are assessment endpoints. Assessment endpoints correspond to the "criteria" discussed in the Santiago Declaration (Santiago Declaration, 1995). An assessment endpoint is a formal expression of the actual societal value that is to be protected (Suter, 1990). For example, it is too nebulous to say that the societal value of biological integrity is important to maintain in a forested ecosystem. Focussing on clearly defined assessment endpoints which can be more quantitatively captured in the definition of biological integrity are more useful in measuring or monitoring ecosystem condition. Related to biological integrity, assessment endpoints regarding biodiversity, productivity, and sustainability can be formulated that are more quantifiable. Assessment endpoints related to consumptive use values also include productivity and sustainability. Non-consumptive use values are com-

posed of assessment endpoints related to non-extractive activities of the resource, such as aesthetics, recreation, and wildlife habitat.

Assessment endpoints are best addressed by articulating the endpoint in the form of an assessment question. The assessment question can be likened to a hypothesis that is formulated at the start of a scientific experiment. A well-formulated assessment question should consist of the following five basic elements:

1. the kind of information desired (extent, status, trends, associations, risk),
2. the population of interest,
3. the spatial and temporal scales of interest,
4. the indicator(s) to be used to measure condition, and
5. the acceptable level of uncertainty associated with the answers.

Here is an example of a well-articulated assessment question for an indicator of forest health using the five elements listed above. The numbers in parentheses are the critical elements.

What proportion (1) of forested area (2) in the outer coastal plain mixed forest province (3) has crown dieback greater than 60% (4), within 10% of the true value with 90% confidence (5)?

At what value of an indicator response is the forest considered healthy or unhealthy? To address this question first requires agreement on two definitions: 1) What is a forest?, and 2) What is forest health?

A forest has been defined as any land with at least 10% of its surface area stocked by trees of any size, including land that formerly had such tree cover, is not currently built-up or developed for agricultural or other non-forest use, and can be naturally or artificially regenerated (USDAFS, 1989; USDAFS, 1993).

There have been numerous attempts to define forest health. Health may be thought of as the absence of conditions that result from disease or other known stresses (Palmer et al., 1992; Rapport, 1992). Aldo Leopold (1949) defined health (not necessarily forest health) as the capacity of the land for self-renewal. Riitters et al. (1990) stated that "no widely accepted definition of forest health exists." If an analogy to humans can be made, it is also true that human health defies definition. Human health is usually based on the individual. Ecosystem health relies on the health of the totality of the individuals comprising the ecosystem. O'Laughlin et al. (1993) reviewed the literature searching for an acceptable definition of forest health and found none. The acceptability of a definition will largely depend on the audience. For example, a timber company may have a different concept of forest health than a public advocacy group. A widely-accepted definition of forest health should contain some of the words used to define a properly functioning ecosystem: sustainable, complex, resilient, productive, stable, balanced, diverse. All of these terms can be used to define forest health for any of the societal values used in FHM, biological integrity, consumptive use and non-consumptive use. O'Laughlin et al. (1995) defined forest health as "a condition of forest ecosystems that sustains their complexity and diversity while providing for human needs." We would like to add to this definition the concept of productivity. Thus the definition of forest health used in this document is that condition of a forest ecosystem that sustains its complexity, diversity, and productivity while providing for human needs.

SELECTING CANDIDATE RESEARCH INDICATORS

Various steps must be taken to select indicators for testing in the FHM program. These steps include:

1) Develop a conceptual model or framework
2) Identify relevant societal values of concern
3) Identify critical components and processes in the model to be addressed
4) Formulate assessment questions
5) Review scientific literature and off-frame data bases for candidate indicators

These steps provide the necessary information to identify candidate indicators and increase the likelihood that selected indicators will have a good chance of meeting certain indicator performance criteria. Steps 1 through 3 are taken by the FHM National Team to identify candidate indicators. Once the indicator has been selected, an indicator leader is identified. The indicator leader is responsible for performing the necessary research to determine the ability of the indicator to meet the indicator performance criteria. Table 1 presents some of the attributes sought in indicator leaders.

Table 1. Indicator leader attributes.

1.	Expert in subject
2.	Publishes (reports and journal articles)
3.	Capable of establishing indicator networks or groups of experts
4.	Evolves the indicator (constantly improves the indicator)
5.	Can spend 50-100% of their time on developing the indicator
6.	Assumes ultimate responsibility for all aspects of the indicator
7.	Conducts off-frame and literature reviews to address indicator development criteria
8.	Ability to model the indicator (conceptually and quantitatively)
9.	Ability to cross-cut with other FHM indicators and other EMAP resource groups
10.	Meets deadlines
11.	Communicates within the program (on conferences call, at meetings, etc.)
12.	Cooperative attitude
13.	Access to technical support (e.g., stats, GIS, equipment, etc.)

GENERAL CONCEPTUAL MODEL

Formulating a conceptual model that shows what forest ecosystem component or process a particular FHM indicator is intended to measure is a critical part of the indicator development process. Moreover, the model should show linkages, either empirical or theoretical, among indicators. Developing such models is extremely important to substantiate the choice of a particular indicator. The model serves four primary purposes:

1) Explicitly defines the framework for indicator selection and interpretations
2) Identifies gaps within the proposed set of indicators
3) Guides the FHM Assessment Team in data analysis and offers plausible associations between stressors and suboptimal conditions
4) Promotes an integrated FHM program and facilitates coordination with other ecological resources (e.g., rangelands, surface waters, wetlands)

FHM scientists developed a conceptual model to assist in the selection of important forest health indicators. FHM scientists selected the indicators currently being tested based on the conceptual model, literature reviews, peer review workshops, and expert opinion. Each indicator addresses at least one assessment question pertaining to certain values that can be easily interpreted by other scientists, policy makers, and the general public. However, many of the selected FHM indicators address multiple assessment endpoints. Redundancy among indicators can be identified by evaluating their respective roles in the conceptual model. Redundancy will be perpetuated only as long as it takes to evaluate the relative values of the indicators in addressing the various assessment endpoints.

Figure 1 presents FHM's conceptual model of the relationship between societal values, assessment questions, and indicators. The relationship between indicators and components of the general conceptual model illustrates that many key attributes of forest ecosystems are addressed by FHM's current suite of indicators. The selected indicators provide quantitative or qualitative links to many of the key processes and components shown in Figure 1. An indicator thus serves as a metric of society's concerns and its perceptions about forest health. Quantitative links between indicators and assessment questions will be derived by analysis of the relationship between indicators and response variables closely associated with defined assessment questions. Some of this information may be found in relevant scientific literature, but in many cases, additional research will be required to obtain this information.

Indicators are not intended to demonstrate cause-and-effect relationships, but will do so in many instances. The preponderance of evidence obtained from monitoring activities may be convincing enough to implicate or clarify certain causal hypotheses, but additional data will usually be required to verify or nullify these hypotheses.

Other attributes of the forest ecosystem, notably fauna and water-related components and processes, are currently being examined by FHM through its collaboration with EMAP. Whether additional indicators need to be added to FHM's current suite, or whether the current suite adequately addresses equivalent or related components and assessment endpoints will be one of the subjects for indicator development in coming years. Some indicators may be developed using data from other monitoring programs.

The formulation of a conceptual model should be viewed as a dynamic process. The utility, validity, and completeness of the model should be continually reevaluated as indicators mature, and advance through the ranks of candidate, pilot research, regional demonstration research, and core status (implementation in national monitoring).

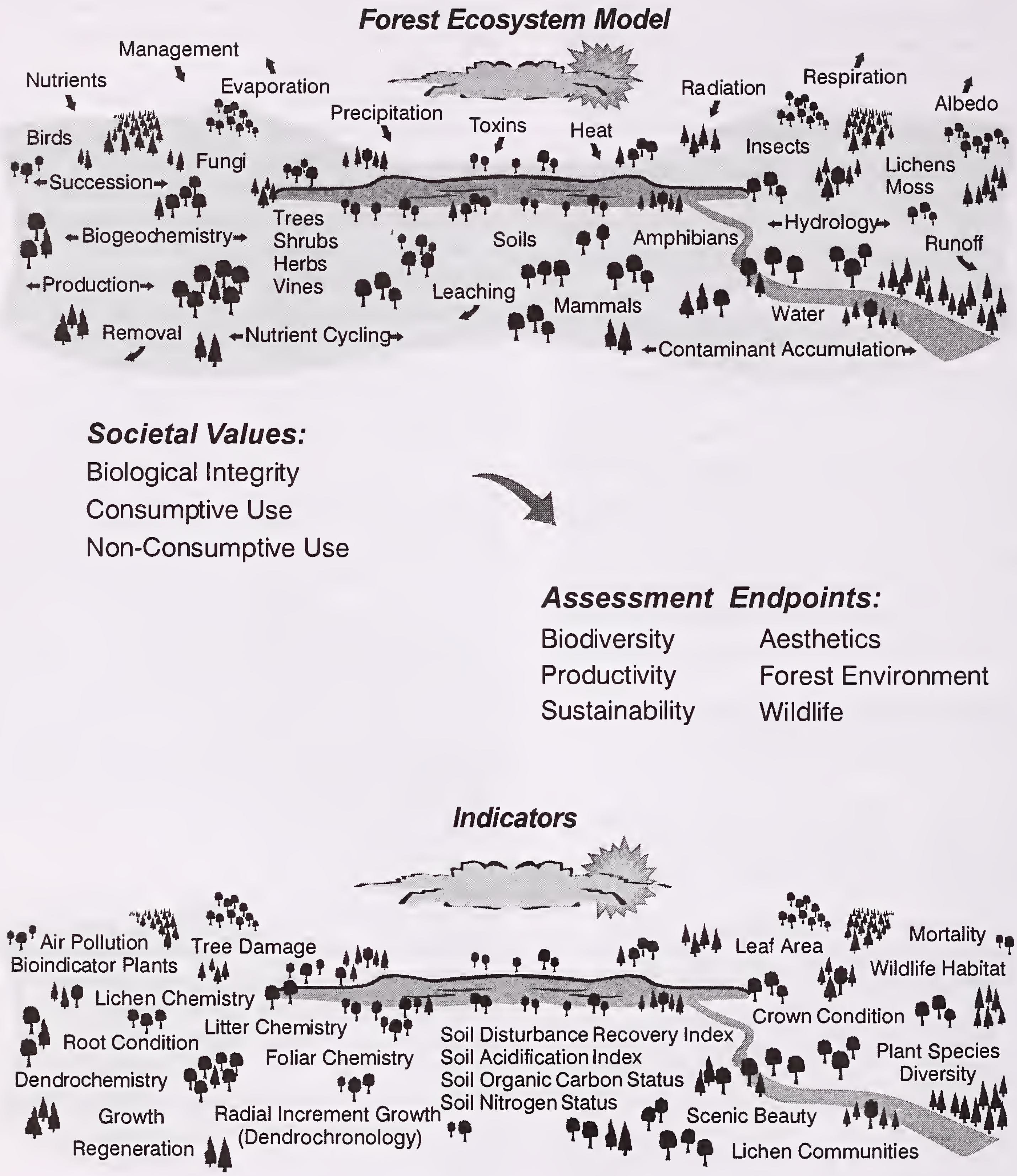

Figure 1. Conceptual model of the interrelationships between forested ecosystem components and processes, major societal values, assessment endpoints, and indicators.

Assessment Endpoint/Measurement Endpoint Relationships

The overall FHM conceptual model can be broken down further into assessment endpoint/measurement endpoint relationships. This level of representation is perhaps the most useful in communicating to Congress, scientists, and the public the hierarchial linkages between values and assessment endpoints. A measurement endpoint is a measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint

(Suter, 1990). A measurement endpoint is often expressed as the statistical or arithmetic summaries of the observations that comprise [sic] the measurement (RAF, 1992). In some cases, the measurement endpoint may be the same as the assessment endpoint. For example the measurement endpoints used to estimate floral biodiversity are directly related to the biodiversity assessment endpoint and are captured by the measurements comprising the FHM's plant biodiversity indicator. As one moves from measurement endpoint to assessment endpoint to societal value, the discussion becomes more tempered by the realization that issues become less and less fixed in objective scientific certainties (measurements endpoints like gravity and general relativity), and become more and more influenced by subjective human value judgements (societal values).

Forest Health Monitoring is designed to respond to the concerns and information needs of the public, land managers, scientists, industry, Congress, and international initiatives dealing with sustainable forest management. The Statement of Forest Principles and Agenda 21, adopted by the United Nations Conference on Environment and Development, held in Rio de Janeiro in June 1992, is a major impetus in selecting and testing forest monitoring indicators. The Statement on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests, also known as the Santiago Declaration, expresses some of the information needs and concerns of the international community (Santiago Declaration, 1995). The "criteria" in the Santiago Declaration correspond to the FHM's assessment endpoints. FHM has been developing and testing indicators that address many of the "criteria" found in the Santiago Declaration.

The indicators that address each assessment endpoint may vary across different spatial scales. The spatial context of the sustainability/productivity, biodiversity/wildlife habitat, and aesthetic assessment endpoints and the change in measurement endpoints at each spatial scale are illustrated in Figure 2.

INDICATORS SELECTED FOR TESTING

Table 2 shows the indicators currently being evaluated in FHM. The table provides a preliminary comparison of several "criteria" and indicators described in the Santiago Declaration and those currently addressed in FHM. The FHM indicators are being considered for implementation in Detection Monitoring, that is, full-scale implementation in all 50 states on the EMAP hexagon grid. FHM continues to test these indicators in various pilot and regional demonstration studies. More thorough evaluation of the indicators may reveal that some are better suited for use in more intensive, perhaps site-specific monitoring activities, referred to in FHM as Evaluation Monitoring. Evaluation Monitoring operates at smaller temporal and spatial scales. Evaluation Monitoring is still in the early stages of development and planning. It is indeed possible that an entirely different suite of indicators will be required to address certain localized problems examined in Evaluation Monitoring.

The general conceptual model (Figure 1) and the assessment endpoint/measurement endpoint relationships (Figure 2) will be further modified and refined to enhance the interpretability of individual indicators and groups of indicators. Figures 1 and 2 should never be considered final versions, but rather should continually change and evolve as our understanding of ecosystem health increases and as FHM moves into different regions of the country. Multiresource conceptual models will be developed in collaboration with other ecological resource groups such as rangeland, agroecosystems, surface waters, and wetlands. Research conducted at Intensive Site Ecosystem Monitoring (ISEM) sites will greatly assist in our ability to develop cross-linkages in multiple resource conceptual models.

New indicators will be added to the FHM program as necessary and tested in various pilot research studies. The formulation of plot-level metrics for any new indicators will be an integral part of indicator development. The general conceptual model (Figure 1) will be modified, if needed, as indicators are added that bring new understanding of relationships or to compensate for discontinued indicators.

In the next three to five years, there will be an increasing move to relate ground-based indicators to remotely sensed measurements. If FHM is to truly be a national program covering all 50 states, it is imperative that remote sensing techniques, as well as data from other monitoring programs, such as Forest Inventory and Analysis and Forest Pest Management, begin to supply some of the necessary information to assess status and trends in forest health.

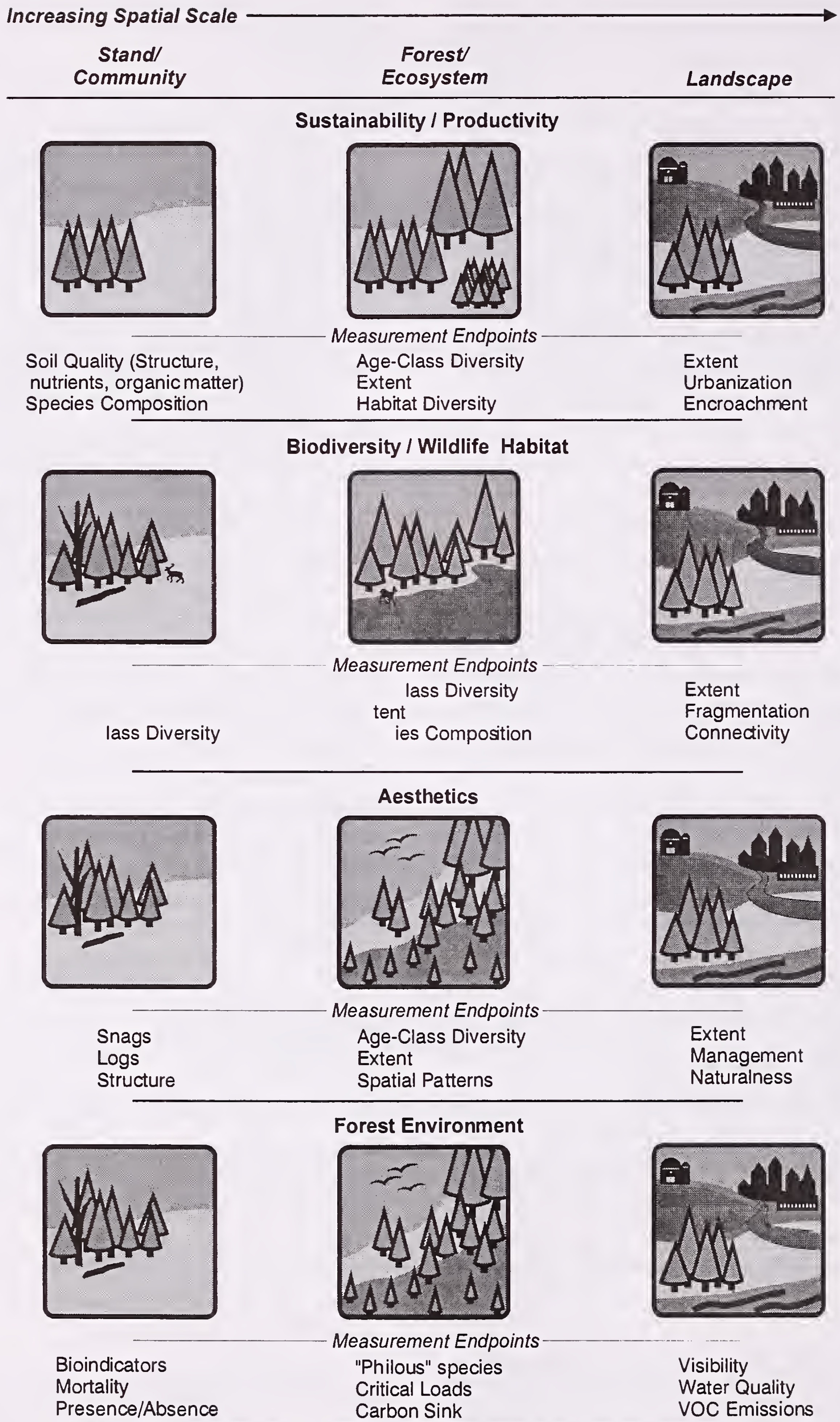

Figure 2. Assessment / measurement endpoint relationships for the sustainability / productivity, biodiversity / wildlife habitat, and aesthetics assessment endpoints at increasing spatial scales.

Table 2. FHM indicators, FHM assessment endpoints, and the Santiago declaration Criteria.

FHM Indicator	FHM Assessment Endpoint	Santiago Declaration Criterion[1]
Basal-Area Growth	Productivity, Sustainability	Criterion 2 - indicator b Criterion 5 - indicator a
Bioindicator Plants - Ozone	Forest Environment	Criterion 3 - indicator b
Branch Evaluation	Productivity, Forest Environment, Aesthetics	Criterion 3 - indicators a and b
Crown Area	Productivity	Criterion 5 - indicator a
Crown Dieback	Productivity, Aesthetics	Criterion 3 - indicator a
Crown Production Efficiency	Productivity	Criterion 5 - indicator a
Crown Transparency	Productivity, Aesthetics	Criterion 5 - indicator a
Crown Shape Ratio	Productivity, Aesthetics	Criterion 5- indicator a
Damage	Productivity, Aesthetics	Criterion 3 - indicator a
Dendrochronology	Productivity, Sustainability	Criterion 5 - indicator a
Dendrochemistry	Sustainability, Forest Environment	Criterion 3 - indicator b Criterion 4 - indicator h
Foliar Chemistry	Sustainability, Forest Environment	Criterion 3 - indicator a, b, and c Criterion 4 - indicator h
Lichen Chemistry	Forest Environment	Criterion 3 - indicator b
Lichen Communities	Biodiversity, Forest Environment	Criterion 1 - Species Diversity
Mortality	Sustainability	Criterion 1 - indicator b
Photosynthetically Active Radiation - Leaf Area	Productivity, Biodiversity	Criterion 3 - indicator a and b
Plant Biodiversity	Sustainability, Biodiversity, Aesthetics	Criterion 1 - Species and Genetic Diversity Criterion 3 - indicator c
Regeneration	Sustainability, Biodiversity	Criterion 1 - Ecosystem Diversity
Root Pathology	Productivity, Sustainability	Criterion 3 - indicator a
Soil Acidification	Productivity, Forest Environment	Criterion 4 - indicator d and h
Soil Horizon Aggradation	Productivity, Sustainability	Criterion 4 - indicator e
Soil Carbon:Nitrogen Ratio	Productivity, Forest Environment	Criterion 4 - indicator d and h
Soil Organic Matter	Productivity, Sustainability	Criterion 4 - indicator a and d
Vegetation Volume	Productivity, Wildlife Habitat	Criterion 5 - indicator a
Wildlife Habitat - songbirds	Biodiversity, Wildlife Habitat	Criterion 1 - Species Diversity

[1]*Santiago Declaration Criteria and Indicators:*
Criterion 1 - Conservation of biological diversity; *indicators*: ecosystem diversity; species diversity, and genetic diversity
Criterion 2 - Maintenance of productive capacity of forest ecosystems; *indicator b* - total growing stock of both merchantable and nonmerchantable tree species on forest land available for timber production
Criterion 3 - Maintenance of forest ecosystem health and vitality; *indicator a* - area and percent of forest affected by processes or agents beyond the range of historic variation, e.g., insects, disease, competition from exotic species, fire, storm, land clearance, permanent flooding, salinisation, and domestic animals, *indicator b* - area and percent of forest land subjected to levels of specific air pollutants (e.g., sulfates, nitrates, ozone) or ultraviolet B that may cause negative impacts on the forest ecosystem, *indicator c* - area and percent of forest land with diminished biological components indicative of changes in fundamental ecological processes
Criterion 4 - Conservation and maintenance of soil and water resources; *indicator a* - area and percent forest land with significant soil erosion, *indicator d* - area and percent of forest land with significantly diminished soil organic matter and/or changes in soil chemical properties, *indicator e* - area and percent with significant compaction or change in soil physical properties resulting from human activities, *indicator h* - area and percent forest land experiencing an accumulation of persistent toxic substances
Criterion 5 - Maintenance of forest contribution to global carbon cycles; *indicator a* - total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages

INDICATOR MEASUREMENTS

An indicator may consist of a single measurement (e.g., dbh is the measurement used in calculating basal-area growth) or it may consist of several measurements combined into a single plot-level value (e.g., the crown production efficiency indicator combines the crown dieback, crown transparency, and crown diameter measurements into a single plot-level term). The formulation of a plot-level value may include averaging measurements to a single mean value, aggregating several plot-level measurements into a single value using a model or formula, or calculating an index. An index can be the combination of several component measurements, in an additive, multiplicative, or intermediate form (Muir and McCune, 1987).

To be interpretable these measurements must be combined or aggregated in a scientifically valid manner to arrive at a plot-level value that is later used in cumulative distribution function (CDF) analysis, GIS spatial analysis, and summary statistical reporting for temporal and spatial trend analyses. The index or plot-level value is evaluated against six indicator performance criteria; environmental impact, simple quantification, unambiguously interpretable, index-

period stability, regional responsiveness, and high signal-to-noise ratio. These criteria will be discussed later in the paper.

Quality Assurance/Quality Control and Measurement Quality Objectives

Forest Health Monitoring has developed a rigorous quality assurance and quality control (QA/QC) program to ensure that all indicator data meet well-defined measurement quality objectives and that the data are of known quality when reported in annual statistical summaries, regional assessment reports, and scientific journals. Controlling measurement error at the individual measurement level is the first line of defense in preventing the collection of data that do not meet the needs of the final data users.

Measurement error of a plot-level indicator is not simply the summation of the precision and bias for the individual raw measurements comprising the index. It is very important to realize that the measurement error of a plot-level indicator comprised of several measurements must be calculated using the formula or model that was used to derive the plot-level index. The calculation of indicator measurement error can be done by using QA/QC field, system, and/or laboratory audit results as input into the index and calculating the measurement quality attributes. Alternatively, although more laborious, when bias and precision cannot be assessed directly, one can propagate measurement error through the index or model using Monte Carlo simulations.

The above discussion clearly points out the need to develop a QA/QC program that not only allows one to document measurement quality attributes and administer corrective action, but also allows one to evaluate the performance of the plot-level indicator using certain performance criteria as a gauge. As indicators are tested in new regions of the country, information on seasonal variability and year-to-year variability will be largely unknown. The initial QA/QC protocols employed in each new region must reflect this lack of information on indicator performance. The QA/QC protocols must be designed such that both measurement quality control objectives are met and that the necessary data are provided for indicator performance evaluation of the plot-level metrics.

INDICATOR TESTING

Once research indicators have been selected (Steps 1 through 5) testing begins. FHM indicators are tested in various pilot and regional demonstration research studies (Step 6). During these studies the plot-level indicators are formulated and the indicator is evaluated against the six indicator performance criteria.

1) Develop a conceptual model or framework
2) Identify relevant societal values of concern
3) Identify critical components and processes in the model to be addressed
4) Formulate assessment questions
5) Review scientific literature and off-frame data bases for candidate indicators
6) Test indicators in pilot and regional demonstration research studies
7) Formulate plot-level indicators and evaluate performance characteristics
8) Review indicators by internal FHM scientists
9) Review indicators by external peer reviewers
10) Identify critical components and processes in the model not being addressed and select new candidate indicators for testing

At the end of each research study, the results of indicator development activities are reviewed internally and externally. The scientific credibility of FHM indicators is of paramount concern to the program.

PILOT STUDIES AND REGIONAL DEMONSTRATIONS

20/20 Pilot Study

All of the aforementioned indicators have been evaluated in various research studies, starting in 1990, with the 20/20 Pilot Study. The 20/20 Pilot Study, named because 20 plots in the Northeast and 20 plots in the Southeast were selected, primarily focused on logistical and economical considerations of indicator selection and evaluation for subsequent research activities. A final report summarized the outcome (Riitters et al., 1991).

Georgia Pilot Study

In 1991, the Georgia Pilot Study was conducted. It served to "fine-tune" indicators that had some problems addressing some of the short-term criteria, such as "simple quantification" (which encompasses cost and logistics) and "unambiguously interpretable". Refinements in methodologies for many of the indicators were recognized and implemented (Alexander et al., 1993).

Western Pilot Study

Similar to the 20/20 Pilot Study, a logistics pilot study was conducted in two western states in 1991, Colorado and California (FHM, 1991). FHM realized that success of certain indicators in the East is no guarantee of success in the West. It was discovered that some minor modifications in methodologies were needed to properly evaluate the suite of indicators in the West. For example, due to the much larger diameter of certain tree species, the annuli about the four subplots were found to be very useful in improving estimates of large-tree mortality rates.

Southeastern Loblolly/Shortleaf Pine Demonstration

A two-year regional demonstration study was conducted in 1992 and 1993 across four states in the southeastern United States comprising a large portion of the loblolly/shortleaf pine forested ecosystem. This regional demonstration study, referred to as the SE DEMO, was of such areal and temporal coverage that after examination of the first year of data, all of the tested indicators could be thoroughly gauged against the six indicator development criteria (Lewis and Conkling, 1994). After the second year of data collection, the two years of data were statistically aggregated and the suite of indicators was intently scrutinized to determine which ones were suitable for advancement into Detection Monitoring Demonstration, and which ones should remain in the research mode, or which ones may be dropped from future consideration (Lewis and Conkling, 1995).

Pacific Northwest Pilot Study

Oregon and Washington are scheduled to join FHM Detection Monitoring in 1996. When a new region is added to Detection Monitoring, FHM scientists consider it advantageous to conduct a pilot study in that region to familiarize the new regional participants with the program and its indicators. The pilot study provided the state cooperators with information on the logistics and costs associated with implementing FHM indicators in their regions. The pilot study also provided FHM scientists with information on the performance characteristics of indicators and enabled them to make modifications in logistics or methodologies that will ensure smooth implementation in the new region (Lewis et al., 1995).

Detection Monitoring Demonstration

Indicators which have shown the greatest merit (i.e., ability to meet most of the performance criteria) have been deployed in the Detection Monitoring Demonstration (DMD) and enable us to obtain critical information needed to address certain performance criteria that would otherwise not readily be available from pilot or demonstration studies; these research studies are somewhat limited in spatial and temporal coverage. Some of the indicators have shown, based on smaller studies or smaller sample sizes, that they should be able to pass the criteria, and hence are being tested on a larger scale in the DMD. Certain criteria, such as "high signal-to-noise ratio", may take several years of pilot-level or regional demonstration studies to obtain the variance estimates necessary to address the criterion. Rather than refrain from deploying indicators in Detection Monitoring that meet most of the criteria, those that lack only data needed to address some of the "long-term" criteria (e.g., year-to-year variability) are being tested in the DMD. It is felt that starting to establish a baseline for forest health using indicators that have passed most of the critical criteria is more advantageous than missing collection of several years of potentially useful baseline data. Those indicators

that are unable to meet more short-term criteria such as "low environmental impact", "simple quantification", and "unambiguously interpretable", will not be tested in the DMD, but will require further off-frame testing and refinement in various research activities.

Thus, the DMD is a valuable tool for testing indicators that meet most of the criteria prior to deployment into actual national implementation. Crown condition, damage, mensuration, and bioindicator plants (in New England only) have been under evaluation in DMD since 1990. Four additional indicators have been identified for evaluation in DMD in 1994, bioindicator plants, lichen communities, photosynthetically active radiation (PAR), and vegetation structure.

INDICATOR DEVELOPMENT CRITERIA

Clearly defined indicator development criteria increase the objectivity, consistency, and depth of indicator evaluations in FHM. The criteria provide guidance for scientists contemplating the addition of new indicators to meet FHM needs. Although certain aspects of the indicator selection and development process are subjective in nature, by presenting and following a well-documented statistical and logical step-by-step process, peer-reviewers will be more apt to comprehend the validity and appreciate the methodical system of indicator evolution. Our decision to modify, continue, suspend, or add certain indicators must be scientifically defensible. Thorough documentation of the thinking process and the logistical/statistical considerations which are part of making such decisions is essential.

Knapp et al. (1990) identified a number of criteria for indicator selection and development. The *critical* criteria listed by Knapp et al. (1990) have been adopted by FHM (Lewis and Conkling, 1994; Lewis, 1995) and are discussed in the following section. The six criteria are shown in Table 3, in order of increasing difficulty. That is, as one moves from the top to the bottom of the table, more quantitative data are needed to satisfactorily address the criteria.

Table 3. Indicator development criteria used to assess performance of FHM indicators.

Criterion	Increasing Difficulty	Type of Data
Low Environmental Impact		Qualitative
Simple Quantification		Qualitative/Quantitative
Unambiguously Interpretable		Qualitative/Quantitative
Index-Period Stability		Quantitative
Regionally Responsive		Quantitative
High Signal-to-Noise Ratio		Quantitative

Data necessary to address some criteria may be available in the scientific literature. Other criteria require additional searches for unpublished data or additional studies specifically designed to provide data to address a certain criterion. Recognizing the lack of existing data, published or unpublished, to answer some of these indicator development criteria, the FHM team designed two studies that were conducted in the second year (1993) of the SE DEMO. These two studies, the QA Reference Plot Study and the Georgia Remeasurement Study, provided critical data for many indicator leaders to help them address the indicator development criteria. The QA Reference Plot Study provided information on the seasonal variability of indicators and the Georgia Remeasurement Study provided information on yearly variability.

Low Environmental Impact

The meaning of environmental impact is as variable as the definition of health. A soil scientist may not consider the excavation of a soil pit as impact to the soil system, but to a botanist concerned with the understory species covering the ground, the soil pit is an intrusion. Similarly, the nutrient cycling expert may not consider excision of a branch from the upper third of a tree crown as an impact, but the forester rating the tree crown for transparency or density may note the absence of such a branch. The sampling required for an indicator that may impact future measurements of its own category, as well as other indicators, should be considered to have high impact potential. Thus, these three components should be addressed by the indicator leader and it should be adequately demonstrated that such impacts are not significant:

- no impact on other current indicator measurements
- no impact on future measurements of own indicator
- no impact on future measurements of other indicators

Trampling is also an important concern. In the SE DEMO, a six-person crew performed its delegated duties on each plot for at least eight hours, walking back and forth over the plot. This created a labyrinth

of topographically and vegetatively defined paths. Continued annual visitation to plots would intensify the disturbance. The effects of trampling have been studied by Cole (1993) and other researchers (Kuss, 1983; Zaslowsky, 1981). A pilot study has been designed to objectively evaluate the plot impact from routine FHM measurement procedures. The first phase of this two-year study will be performed by a University of Vermont FHM research crew during the 1995 field season.

Simple Quantification

The simple quantification criterion means that the indicator can be quantified in a synoptic monitoring program or by cost-effective automated monitoring (e.g., passive samplers, remote sensing). This requires that the measurements comprising the indicator be logistically feasible. Furthermore, FHM also considers cost-effectiveness for synoptic monitoring methods under this criterion.

The simple quantification criterion consists of four components:

- Instruments/measurements are reliable and protocols for field/laboratory data collection and data validation and verification have developed
- Difficulty and time requirements of the measurement process have been fully evaluated and are acceptable
- Data or specimens can be collected in one day
- Is affordable in FHM detection monitoring

The first component consists of logistical, quality assurance, and information management considerations. Methods or instruments should be available for deployment of the method in the field. The protocols should be reliable, reproducible, easily understood, and easy to follow in the field. Certification and field or laboratory audits should attest to these facts.

There is another aspect of data collection and quantification that may be implicit in the first component, but it needs to be stated more succinctly. The data must be able to be processed and analyzed by not only the indicator leader but other scientists internal and external to the program. To do this, the indicator leader must demonstrate the ability to develop protocols for data verification/validation that can be automated and be able to transfer this technology to regional information management personnel. This is a QA/QC and Information Management issue. If the indicator data are so complex that only the indicator leader or their representative can verify/validate them, the indicator does not meet the simple quantification criterion and is not ready for implementation in the national monitoring program.

Verification/validation rules must also be repeatable. Otherwise, the final verified/validated data set cannot meet the index-period stability or the high signal-to-noise ratio criteria. The indicator cannot meet these two criteria, nor the simple quantification criterion, if the data cannot be verified/validated in such a way that: (1) the same results are obtained if the same data are run through the verification/validation process ten times; and (2) in different years, if/when the indicator leader or methods change, the verification/validation process changes to the point that it affects the final data. For example, if suddenly a large proportion of previously flagged high values are no longer flagged as bad values, the plot-level means would rise across the region and country. There would appear to have been a shift in the index value when, in fact, there was a change in the verification/ validation protocols -- this is a calibration problem that is difficult to detect in the verification/validation process. One possible solution to this problem would be to have a Standard Reference File of raw data with an accompanying verified/validated final data set, either actual or contrived, that would be run through the verification/validation process at the end of each field season to corroborate that the same final results are produced. This is similar to a standard reference material that is analyzed in the laboratory by an atomic absorption spectrophotometer or other instrument, to ascertain that the calibration is valid and accurate results are attainable.

At first glance, those indicators that depend on laboratory analysis of specimens collected in the field would seem to be an exception to this rule, such as the lichen community indicator. In this case, specimens need to be identified by an expert lichenologist. However, data verification/validation systems should also be developed for these types of indicators, e.g., lichen communities, vegetation structure, and some other indicator categories that are still in the pilot and demonstration modes, such as soils, dendrochemistry, lichen chemistry, and foliar chemistry. For example, the botanist forwards unidentified plant specimens to a herbarium for identification. The herbarium

expert must enter data into a computer. The herbarium data should still be subject to the same code-checking verification/validation process that is used for data downloaded from the field personal data recorder (PDR). Sample coding should be done in such a way that verification/validation is feasible when combining the herbarium data with the PDR data to produce the finished data set. In the case of lichens, if there are checks to be made on the data, they should be made on the data as entered by the lichenologist. Using a list of known lichen species, with specific codes for each species, data could be quickly checked to verify that a recorded specimen is in fact on the legal species list (for that region). In the case of soils or foliar chemistry, where data are analyzed at a laboratory, the data verification/validation programs have already been prepared for checking the validity of the data package before it leaves the analytical laboratory. Confirmation by the laboratory of unusual values is requested. Samples may require reanalysis if confirmed values are outside acceptable QA/QC limits. These programs insert the verification/validation step as far up the sample analysis chain as possible, permitting more timely verification of spurious values and any necessary corrective action (e.g., sample reanalysis).

Although not specified as an FHM program-wide requirement, the measurements for an indicator should be able to be collected in one day on each plot, or gathered in one day for later analysis. These requirements are stated above as components 2 and 3 of the criterion. This does not preclude installation of passive samplers or integrative monitoring devices for data collection. However, the installation of such devices must also be economically and logistically feasible. The time-on-plot requirements for collecting the data must be well-documented and deemed acceptable by the FHM National Management team prior to deployment of the indicator into the field within the context of national implementation. Various pilot and demonstration research studies in which the indicator in question is tested as part of a cadre of indicators may be necessary to obtain truly representative estimates. No indicator will be deployed in a Regional Demonstration of Detection Monitoring without such time estimates available.

Finally, as stated in component 4, cost is an obvious factor given the magnitude of FHM, especially after implementation in all 50 states is realized. Measurements that require expensive instrumentation or several visits to the plot each year, may be economically and logistically prohibitive.

The components that comprise the simple quantification criterion deal largely with requirements that must be met at the measurement level of the indicator. The remaining criteria begin to focus on whether plot-level indices can be derived by aggregating measurement-level data in an ecologically meaningful way and whether these plot-level indices meet an acceptable level of uncertainty for the intended data use.

Unambiguously Interpretable

This criterion focuses on the ecological relevance of the indicator within the context of FHM's conceptual models. The criterion can be partitioned into six components:

- fits into FHM conceptual model
- answers assessment questions of interest about forest ecosystems
- support for indicator from literature review and field studies
- formula for indicator
- aggregation to plot-level index
- reasonable nominal/subnominal threshold

The indicator must be related unambiguously to an assessment endpoint. The assessment endpoint, in turn, must relate to an important societal value. Many FHM indicators consist of several different measurements made on many components of the ecosystem, on each of the four subplots. These measurements should be well-documented in the literature and unequivocally demonstrate their ecological merit.

The ability to relate an indictor to an assessment endpoint is simplified if the endpoint is stated in the form of an assessment question. To unambiguously relate to an assessment question, measurements must be reduced to a single, plot-level value. The plot-level value may be obtained by developing a plot-level index by combining several plot-level measurements using a model or formula. Alternatively, the index may simply be the plot's average value for a single measurement made on various components of the ecosystem. A threshold should also be defined for separating the population into nominal (good) and subnominal (poor) categories whenever appropri-

ate. For most indicators, the threshold should be based on the following sources of information, listed in order of priority:

- literature review
- existing data
- manipulative studies
- stress gradient studies
- retrospective analysis
- expert opinion
- public opinion

For some indicators, such as those related to aesthetics, public opinion will play a much greater role in the establishment of meaningful thresholds. Some thresholds can be defined through searches of scientific literature and existing data bases. For example, if existing data indicate that 4 is poor and 6 is acceptable, then we can cite these references and suggest 5 as a legitimate threshold. If the data indicate that 0.1 is poor and 100 is acceptable, then we cannot suggest a threshold of 5, however, we can determine the range in which the threshold falls. It is important to note that inadequate study of the scientific literature may hinder this effort. If these sources fail to provide the needed information, research studies or retrospective analysis should be performed. Since many plot-level indicators are relatively unique aggregations of plot measurements, the literature may not contain relevant information and, therefore, field research may be required to obtain the necessary information. In some instances, knowledge of whether an index value is increasing or decreasing over time may be the sole indicator of change and serve as a threshold. The slope of the change may be useful in delineating a threshold for the indicator. Alternatively, the variability in the plot-level values may serve as the indicator. Change is the norm rather the exception for forest ecosystems. The historical range in variability is as important as the rate of change in determining ecosystem health (Morgan et al., 1994).

Given some idea of the appropriate range for a threshold, manipulative, stress gradient, or retrospective studies can be performed to further define the threshold. Quality assurance and quality control in such studies are crucial to accurately define the threshold level. Once again, the scientific literature may provide important information. Studies should be designed to develop an indicator, i.e., demonstrate a biological or ecological response relationship. The closer the biological/ecological response corresponds to an assessment endpoint, the easier it will be to develop an indicator-level conceptual model, and to demonstrate that an observed population change in an indicator can be interpreted as a quantifiable change in the assessment endpoint.

Expert opinion is sought to confirm established thresholds or to assist in setting thresholds if the aforementioned procedures do not provide meaningful information. Manipulative or gradient studies may be much too costly and therefore expert opinion will be needed to provide the information (Karr and Dudley, 1981). Public opinion is sought for certain indicators related to somewhat vague assessment endpoints such as aesthetics.

Thresholds will vary based on public perception. For example, the definition of productivity to a timber resource specialist may differ markedly from that of a forest ecologist or wildlife biologist. There is no right or wrong definition; the definition depends on the data user's needs. The same is true for thresholds. The threshold also may be related to the poststratification procedure applied to the data. For instance, if data are stratified by forest type, the crown-dieback threshold for the spruce-fir forest type may be quite different than that for the oak-hickory forest type. Established thresholds are under continuous review and are adjusted accordingly as more knowledge is gathered.

Index-Period Stability

Index period in the context of FHM is the time window in which samples are collected. This criterion can be referred to as the natural variability of the indicator found during the field season, which encompasses all measurement effects as well. Currently, data collection for most indicators is during the growing season, generally from early June to early September in most regions (this window may vary depending on the region). The plot-level indicator value must be stable over that time frame. The indicator should be judged solely on evidence showing that the indicator is stable over diurnal and seasonal time scales and exhibits low measurement error. An inability to collect data that support this stability reflects a defect in the indicator. This criterion can be partitioned into two fundamental components:

- stable over sampling window (June - September)

- low measurement error

Diurnal and seasonal variation are important sources of variability that may affect index-period stability. Phenologic and climatic influences on the measurements must be either nonsignificant or normalized to minimize their contribution to the variability.

Other errors associated with the measurement system are included in index-period variability, such as crew-to-crew variability. Multiple measurements by multiple crews were taken during the 1993 field season in the SE DEMO and in 1994 in CA, CO, and the Pacific Northwest Pilot, using a balanced, incomplete block design. These additional measurements will provide a direct estimate of system measurement error, natural variability, and between-crew variability. A target Data Quality Objective (DQO) has been defined by EMAP and FHM for this criterion:

$$\frac{\textit{Index} \quad \textit{Period Variability} + \textit{Measurement Error}}{\textit{Plot} - \textit{to} - \textit{Plot Variability}} \leq 10\%$$

If the sum is less than 10% of the plot-to-plot variance, then the indicator meets the index-period stability criterion. Ten percent is considered to be an inconsequential amount of extraneous variability and will not significantly bias the cumulative distribution functions for the indicator (Urquhart et al., 1992).

This criterion clearly points out the need for a unified QA and Indicator Development strategy for indicator deployment and testing. At the raw measurement level, QA/QC target values are necessary to demonstrate that the measurement system is under control and whether corrective action is required. At the plot level, the plot-level indicator value must rely on the same QA/QC data to demonstrate if the index-period variability is being achieved. FHM is currently testing indicators in regions where very little information is available to address index-period variability. Implementation of a unified QA/Indicator Development Strategy is critical in regions where FHM is currently testing indicators, as well as in any new regions where monitoring is initiated.

Regional Responsiveness

The objective of this criterion is to assess how well the indicator value determines status and detects change over a region. This criterion focuses on issues of post-stratification of the data and the ability to compare the indicator's plot-level value across major ecological strata or habitats of interest. In other words, this criterion asks the question whether the indicator is sufficiently widespread to provide a regionally-relevant assessment. A difference in an indicator value must reflect a difference in site characteristics, either over time or across space. This difference does not necessarily have to be independent of external variables, such as climate. For example, low levels in the calcium index for foliage due to drought do not mean the index is defective. Provided such external-variable data (e.g., precipitation) are available, the index can be evaluated in light of the external variable, or the index can incorporate these sources of variability into its derivation.

Assuming that the indicator has met the index-period variability DQO, the following two components should be considered with respect to regional responsiveness:

- can obtain at least 50 plots in each stratum of interest in a given region
- can be calibrated across ecosystems or forest types or regions (or does no post-stratification of the resource and can justify that no calibration is needed)

FHM is unable to collect sufficient data to make statements to fully characterize each individual plot. The objective of the program is to collect enough data at each plot to characterize the region or domain of interest. Our goal is to have bias and variability within acceptable limits so that they do not add an unacceptable level of uncertainty to the population estimates (e.g., are not noticeable in CDFs). Generally, the indicator should be measurable on 50 or more plots. The less frequently an indicator is found the wider the confidence intervals are around the CDF at a given plot-level value, and hence the lower our confidence in making statements about the proportion of the population in poor or subnominal condition.

The target DQO for this criterion is as follows: the percentage difference between the upper and lower confidence bounds on the CDF should be less than ten percent at the point where the nominal/subnominal threshold crosses the CDF. If a threshold falls at that point and the difference between either one or both of the confidence bounds and the CDF is greater than ten percent, this DQO will be exceeded. The probability-based sampling design of FHM uses

Horvitz-Thompson estimation, so that our CDF bounds should, in general, be tighter than for a similarly-sized simple random sample.

High Signal-to-Noise Ratio

This criterion describes the trend-detection effectiveness of an indicator, and is perhaps the most difficult to address due to the need for long-term monitoring data in similar ecosystems or forest types using similar measurements. The variance components of the signal-to-noise ratio criterion are:

- Year-to-year regional variability
- Year-by-plot interaction
- Residual error (index-period variability and measurement error)

The FHM target DQO is to discern a 2% per year linear trend over a region for ten years, with a 0.20 probability of a Type I error, and a power of 70%. The ability of an FHM indicator to meet this DQO can be evaluated on multiple plots measured each year for multiple years. The variance components needed to address this criterion include the year-to-year and year-by-plot interaction terms.

Plots will be sampled on a one-quarter interpenetrating cycle. That is, using a rotating panel design, each plot will be remeasured every forth year. Plot-to-plot differences are not as important as year-to-year variability because the repeated visits every fourth year allow data analysis in a manner similar to a paired t-test or repeated measures analysis. Due to the large number of sites, the ability to detect a trend is different than the ability to see a change at a single site. For example, if we wish to detect a 10% change between two visits at one site and our remeasurement error is 20%, we cannot discern this change. However, if we visit 35 sites twice, given the same remeasurement error (i.e., 20%) and given the same trend-detection goal (i.e., 10%), a significance level of 0.05 (analogous to a 95% confidence interval) is realized, with a power of over 80%. Furthermore, if 200 sites are revisited, with the same error and detection goals, the same 0.05 significance level and power (80%) are achieved. The high trend-detection power at increasing numbers of plots is due to the fact that the standard error of the mean decreases as the sample size increases.

NATIONAL IMPLEMENTATION - THE ROAD TO CORE STATUS

The term core status refers to the final stage in which an indicator has satisfactorily passed through the indicator development process and has the scientific validity to serve as a nationally implemented indicator of forest health in Detection Monitoring. The process to reach core status includes:

- Identifying and selecting attributes of forest condition based on societal values and assessment endpoints
- Developing plot-level indices that address those values and assessment endpoints
- Evaluating indicators in terms of specific performance standards
- Implementing successful indicators in Detection Monitoring Demonstrations
- Internal and external review and acceptance of the indicators at the national level

SUMMARY

The U.S. Forest Health Monitoring Program is a multiagency program with leadership shared between the U.S. Environmental Protection Agency and the U.S. Department of Agriculture Forest Service. A methodical approach to indicator selection and testing has been developed by FHM. Well-defined performance criteria assist in the evaluation of indicators. This approach can be adopted by other forest monitoring programs or by other ecological resource monitoring. Multiresource indicators can be identified and tested using the FHM approach.

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Soil and Vegetation Indicators for Assessment of Rangeland Ecological Condition[1]

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Abstract.—Indicators of rangeland ecological condition should be (1) quantitative, (2) rapid, (3) repeatable, (4) easily communicated, and (5) susceptible to sensitivity analysis. Most importantly, the indicators should be related to ecosystem function and to the capacity of the system to resist and recover from disturbance. Based on these criteria, we have developed a suite of indicators for North American desert rangelands. Most of these rangelands are located on fragile, nutrient- and organic matter-poor soils and suffer from periodic moisture deficits. Consequently, we have focused on indicators which reflect the capacity of the system to trap and retain soil and water resources. These indicators include size of bare soil patches, cryptogamic crust cover and soil surface stability, and the ratio of long-lived to short-lived perennials. Another suite of indicators reflect rangeland productivity. These include proportion of total perennial plant cover of species palatable to livestock as well as total biomass production. We have developed and tested these and a number of other indicators in a wide variety of plant communities with known disturbance histories at the Jornada Experimental Range in the Chihuahuan Desert in New Mexico, and validated them on cooler, more mesic rangelands in Idaho and Oregon, as well as an arid site in Utah. We will present results from the Chihuahuan Desert evaluation, together with a preliminary version of a variable-weighting system to combine these indicators into flexible indices of ecological condition which can be adapted to address the objectives of individual agencies and land managers.

INTRODUCTION

Ecological condition is defined as the relative capacity of a system to (1) perform selected functions, and (2) to maintain these functions following disturbance through processes of resistance and recovery. The emphasis of this definition is on *selected* functions. Ecosystems perform a variety of functions. While many of these functions are mutually compatible, the optimization of one function may at times require a reduction in the capacity to fulfill a second function. For example, the revegetation of graded coal mine spoils in southern Ohio with aggressive perennial grasses optimizes the ecological function of soil conservation in a relatively short period of time. However, reestablishment of the highly diverse native forest system is blocked by competition from the grasses. The forest system, once established, would more effectively fulfill a number of functions

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than the perennial grassland, including biodiversity conservation, wood production, microclimate modification, and carbon storage.

The determination of the relative importance of various functions (and thus the ultimate determination of ecological condition) is a policy issue which must be completed independently of the evaluation of the relative capacity of the system to perform each function. Consequently, we have divided the process for developing an ecological condition indicator system into four stages. Stage I involves selecting the ecosystem functions of particular interest and is completed by managers and policy-makers in consultation with scientists. Scientists select and develop function-specific indicators in stage II and then combine them to assess each function individually in stage III. These functions are then combined by teams of policy-makers, managers and scientists in stage IV according to the relative societal values placed on each function. A feedback loop clearly exists through the four stages. The relative weights assigned to various indicators and functions can be modified as our understanding of ecological processes and the relative value society places on different functions evolve.

STAGE I: FUNCTION SELECTION

The ecosystem functions selected should be based on current and anticipated future societal values. While many functions overlap, few can be characterized by an identical set of indicators. Consequently, it is important to incorporate the views of as many interested parties as possible at this stage in order to identify all potentially relevant functions.

STAGE II: INDICATOR SELECTION AND DEVELOPMENT

Indicator Selection Criteria

Indicators of ecological condition should be (1) quantitative, (2) rapid, (3) repeatable, (4) easily communicated, and (5) susceptible to sensitivity analysis. Most importantly, the indicators should be related to ecosystem function and to the capacity of the system to resist and recover from disturbance.

Quantitative

Quantitative indicators are preferred over qualitative or subjective indicators in nearly all cases because they tend to be more repeatable and are easier to combine with other indicators. However, some ecosystem functions, such as providing scenic value, are difficult to measure quantitatively. In these cases, rating or ranking systems may be applied to subjective assessments to provide a semi-quantitative indicator. The numerical values or ranks can then be calibrated with quantitative data. For example, Watters *et al.* (in press) developed an exponential relationship between a subjective "site stability rating" and sediment yield predicted by WEPP (Water Erosion Prediction Project). Any evaluation system which includes this approach should include a precise description of how the individuals making the subjective assessments are to be selected, as well as the type of guidance which these individuals will receive. In many situations, however, quantitative indicators can and should be substituted for qualitative indicators by using quantitative parameters which have been calibrated with qualitative assessments in controlled studies.

Rapid

The indicators and measurements selected should be as rapid as possible in order to minimize costs and to permit data collection at as many sites as possible. There are at least four factors which determine how rapidly the information needed for an indicator can be collected: (1) time per measurement, including preparation, (2) number of different types of measurements needed for the indicator, (3) number of replicate measurements needed per site, and (4) operator training time. The number of replicates needed per site depends on the ratio of the expected maximum range of values between sites to the expected within-site variance. This can be thought of as one component of a signal-to-noise ratio for the indicator. The other component depends on how accurately and precisely an indicator reflects the ecosystem function of interest. Measurements and indicators with a high signal-to-noise ratio will require fewer within-site replications.

Site assessment speed can frequently be increased by recognizing that different indicators have different signal-to-noise ratios at different spatial and tem-

poral scales and therefore require different levels of replication. For example, while relatively large plots are required to assess shrub or tree cover, annual and perennial grasses and forbs can often be quantified in several smaller sub-plots.

Repeatable

Identifying indicators which can be consistently evaluated by a wide variety of observers over a number of years or decades is one the most difficult and important tasks for indicator development. While a number of quality-assurance techniques have been developed to promote observer consistency within a team operating during a single season, it is much more difficult to maintain a high level of uniformity between years, even when the same observers are involved. Indicators which are simpler and involve fewer subjective decisions will tend to be more repeatable over the long-term.

Methods for collecting data should be clearly defined before actual data collection begins. Any changes to the methodology should be explicitly recorded and reported with the results, even if it does not immediately appear that these changes will have any impact on the results.

Easily Communicated

Where possible, the connection between the indicator and the function should be intuitively obvious to the general public. Clear connections between indicators and functions may minimize future conflicts over interpretation of the assessments and facilitate the assignment of relative weights to each indicator. The selection of indicators with an intuitive connection to function should not, however, come at the expense of the other four factors. For example, while large-scale rainfall simulation and natural precipitation runoff plots are clearly related to hydrological function, their high cost generally precludes sufficient replication.

Susceptible to Sensitivity Analysis

Ideally, it should be possible to test the sensitivity of the indicators against quantitative changes in the capacity of the system to perform the selected function(s). This type of information is frequently not available. A suitable substitute is to test the indicators along gradients which have a known disturbance history.

Related to Function and System Resistance/ Resilience

The most important attribute of an indicator is its ability to reflect changes in the capacity of the system to perform selected functions, and to maintain those functions following disturbance. Indicators which reflect changes in the capacity of the system to maintain functions following disturbance serve as a kind of "early warning system" for those areas which are "at risk". These are particularly useful in targeting areas for remediation measures.

North American forests and rangelands are required to perform a wide variety of functions, including (1) soil and water conservation for flood control, (2) groundwater and surface water recharge, (3) and maintenance of clear streams for fish production and human consumption, (4) animal production for food and fiber, (5) wildlife conservation for sightseeing and hunting, (6) biodiversity conservation of non-game species, and (7) open space conservation for fulfillment of humans' desire to temporarily distance themselves from other members of our own species (Klinkenborg 1995). Increasingly, forests and rangelands outside of national parks are also viewed as sinks for increases in carbon emissions from burning of fossil fuels. Soil and water conservation is the most fundamental of the functions listed as it is necessary for the preservation of the other functions. While there are a few cases in which soil erosion can lead to temporary increases in productivity due to the exposure of more nutrient-rich subsoil, or in which catastrophic events can increase biodiversity by increasing landscape heterogeneity, a large proportion of the earth's rangelands and forests are limited to soils which have bedrock or a limiting horizon close to the surface, soils in which most of the nutrient capital is confined to the top few centimeters, or soils in which water limits plant growth throughout most of the year. In these systems, increases in the "leakiness" of the system with respect to soil, water and nutrients nearly always leads to degradation in other ecosystem functions.

The capacity of the system to maintain or recover ecosystem functions following disturbance depends on both the integrity or condition of the system and on the nature of the disturbance: disturbance history, seasonality and time scale, intensity and frequency, and combination with other disturbances or stressors. The nature of the expected disturbance regime must be defined before ecosystem condition can be

assessed. Using the analogy of human health to illustrate the importance of disturbance history, a doctor working in the infectious diseases ward of a hospital in Alberta, Canada would be expected to have an extremely robust immune system. The same doctor, however, may succumb to heat exhaustion following only a brief walk in the Sonoran Desert of Mexico. Similarly, a Mojave desert system which has evolved to resist and recover from drought may collapse when subjected off-road vehicle traffic.

Even in cases in which the system has evolved in response to a particular type of disturbance, changes in the timing, intensity, frequency, can yield significant differences in relative ecosystem condition relative to the new disturbance regime. For example, Chihuahuan desert rangelands appear to be much more resistant to winter than to summer grazing and least resistant to grazing immediately following drought.

Timing of Measurements

The time of year when measurements are to be made should be chosen during the indicator selection process. Where possible, measurements should be made during a period when (1) the indicator is relatively stable, and (2) the indicator best reflects ecosystem status within the context of long-term trends in ecosystem condition.

STAGE III: INTEGRATION OF MEASUREMENTS, INDICATORS, AND FUNCTIONS FOR ASSESSMENT OF ECOLOGICAL CONDITION

Very few ecosystem functions can be assessed using only one indicator. We have adopted a relatively simple, flexible system for integrating indicators. The process is similar to that used by Karlen *et al.* (1994) for the evaluation of cropland soil quality. The following steps are involved: (1) conversion of each indicator value to a standard score (Figure 1), (2) assignment of weights to each factor at each level, and (3) combination of scores to yield an integrated index for each ecosystem function (Table 1).

Conversions of Factor Values to Scores

The value for each factor is scored on a scale of 0 to 1 based on a scoring function, with scores of 0 and 1 signifying poor and excellent, respectively. Most factors follow one of the standard scoring functions illustrated in Figure 1; however many other scoring functions are possible.

Selection of scoring functions should ultimately be based on calibration from field data. However, few data are available which can be used to directly calibrate indicators against current ecosystem function and even fewer studies have yielded quantita-

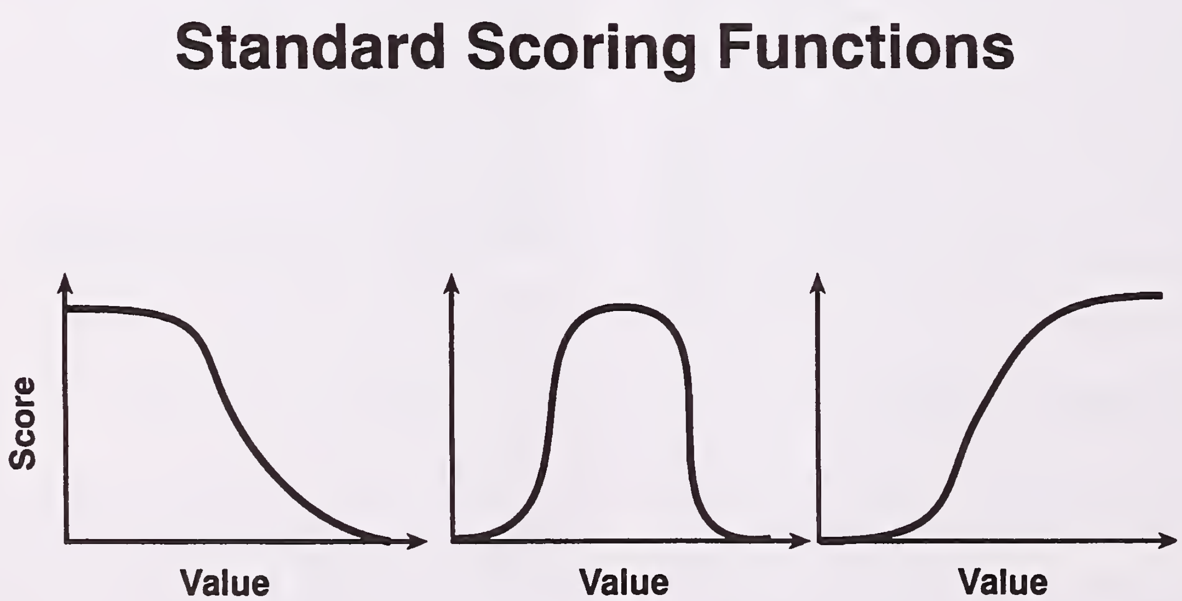


Figure 1. Sample standard scoring functions for converting indicator values (from data) to a score between 0 and 1. Other curve shapes are possible. To determine a score, locate the value on the x-axis and locate the corresponding coordinate to the line on the y-axis.

Table 1. System for combining indicators into scores for individual functions and function scores into a single condition rating. Note that the condition score should always be reported with the contributing function scores. See text description of Stage III and Stage IV for more detail.

STAGE III				STAGE IV			
Indicator Name	Value	$Score_i$[1] (0-1)	$Weight_i$ (0-1)	Function Name	$Score_j$[2] (0-1)	$Weight_j$ (0-1)	Condition Score[3] (0-1)
a	30	0.8	0.5				
b	2	1.0	0.2				
c	5	0.7	0.1				
d	12	0.8	0.3	A	0.81	0.6	
a	30	0.4	0.5				
e	342	0.2	0.5	B	0.21	0.2	
f	65	0.9	1	C	0.90	0.2	0.71

[1]Indicator score: from standard scoring functions
[2]Function score: $\sum[(\text{Indicator score})_i * (\text{Indicator weight})_i]$
[3]Condition score: $\sum[(\text{Function score})_j * (\text{Function weight})_j]$

tive relationships between indicators and ecosystem resistance and resilience. The most comprehensive literature in this area is related to the development of erosion and erosion-productivity models such as the USLE (Universal Soil Loss Equation), RUSLE (Revised Universal Soil Loss Equation), EUROSEM (European Soil Erosion Model), MEDALUS (Mediterranean Desertification and Land Use), and WEPP (Water Erosion Prediction Project) (Nearing *et al.* 1994). However, these models were designed primarily for use on croplands and/or involve measurements which are not cost-effective for large-scale monitoring programs. More process-level studies are needed to quantify indicator-ecosystem function relationships.

In the absence of these studies, however, scoring functions can be selected by groups of experts for each function. As more information becomes available, the scoring functions can be revised retroactively in the computer database and reports on ecosystem condition trends modified accordingly. The potential for abuse of this system clearly exists and the revision process would need to be documented and subjected to independent peer-review.

Assignments of Weights

After the values of each factor have been scored, the factors (measurements or indicators) must be assigned a relative weight with the sum of the weights for each function set equal to one. The approach used is similar to that applied to scoring functions and is subject to the same limitations.

Combination of Scores

The scores are combined by summing the product of the score for each factor with its respective weight, yielding a new score ranging from 0 to 1. For example, in Table 1, the score for function A is simply the sum of the individual products of the scores and weights for indicators a, b, c, and d. Individual indicators can be used to assess more than one function, as illustrated in Table 1 for indicator a, which is used to calculate scores for both functions A and B.

STAGE IV: COMBINATION OF SELECTED ECOSYSTEM FUNCTIONS

Stage IV is very similar to stage III except that the scores are based on combinations of function scores (from Stage III) and the weights are based on current and anticipated future societal values. When reporting ecological condition ratings based on combinations of function scores, the component function scores should also be reported in order to facilitate interpretation of the composite rating. The advantage of this system is that it is simple and flexible enough to be used to facilitate more objective discus-

sion by policy-makers, managers and the general public on what actually constitutes "good" or "poor" ecological condition. Selecting ecosystem functions and assigning weights to those functions can help identify areas of consensus as well as areas in which trade-offs might be made.

CASE STUDY

The following case study is based on preliminary data from the USDA-ARS Jornada Experimental Range and the Chihuahuan Desert Rangeland Research Center. Both are located in the northern Chihuahuan Desert in southern New Mexico, USA. This study is incomplete and is presented only to illustrate the points discussed above. A more comprehensive analysis of a complete set of indicators and a more thorough presentation of this approach will be presented in forthcoming publications.

For the purposes of this paper, we have selected three important functions which rangelands perform. The first is their capacity to conserve soil and water resources. The second is their capacity to provide forage for animal production. The third is their capacity to conserve biodiversity. These three functions were selected because of the relatively high value which various sectors of society place on each. Each function is discussed in the context of an arid rangeland system in the Chihuahuan Desert where annual precipitation averages 225 mm/yr. The sensitivity of selected indicators is illustrated with a comparison of average values at each of three pairs of relatively undisturbed (lightly to moderately grazed grassland) and heavily disturbed (areas around watering points) sites.

Function 1: Conservation of Soil & Water Resources

Indicators

Water may be lost from the system through runoff, evapotranspiration, and drainage beyond the rooting zone. The latter rarely occurs. Runoff then is the primary cause of non-evapotranspirative water losses. Soil can be lost or redistributed through both water (runoff) and wind erosion. However, wind and water redistribute soil fractions differently. Nutrients may be lost through either type of erosion and, rarely, leaching beyond the rooting zone. Increased mineralization of soil organic matter associated with breakdown in soil structure can also significantly deplete soil nutrient storage (for nitrogen) and nutrient retention capacity (for cations). Other processes may be important for specific limiting nutrients, such as denitrification for nitrogen and fixation for phosphorus. For most arid and semi-arid rangeland ecosystems, however, increases in losses of soil, water and nutrients are associated with increased runoff due to reductions in the rate of water movement into the soil (infiltration capacity) and the amount of time water remains ponded on the surface (flow rates). Flow rates, in turn are a function of both slope, which is recorded as a semi-permanent site characteristic, and the surface roughness and density of obstructions to runoff, including plant bases, large debris, and litter accumulations.

The following indicators are among those which may be used to assess infiltration capacity and runoff under natural rainfall, which is too expensive to measure directly: total plant cover, long-lived grass cover, average length of bare patches (parallel to slope), soil surface stability (using slake test (Whitford *et al.* in preparation)). Soil texture (by hand) is recorded as a site characteristic. Additional indicators currently under consideration are listed in Table 2. All of the measurements necessary for these indica-

Table 2. List of possible indicators for three functions which rangeland ecosystems perform. The list is not exhaustive and evaluation is in progress for many of the indicators listed below.

ECOSYSTEM FUNCTION: Conservation of soil and water resources	
	Long-lived grass cover
	Total plant cover
	Mean length of bare soil patches
	Soil stability (field slake test)
	Cryptogamic crust cover
	Legume cover (potential nitrogen fixers)
	Size and spatial distribution of litter patches, root density, and depth (based on species composition and cover)
	Soil texture
	Clay % ratio (vegetated/bare)
	Infiltration capacity
	Penetrometer resistance
	Rill density and morphology
	Soil aggregate stability
ECOSYSTEM FUNCTION: Animal production	
	Palatable vegetation index
	Forage value index
	Soil productivity index
	Toxic species cover (extent and duration)
ECOSYSTEM FUNCTION: Biodiversity conservation	
	Native grass cover
	Species richness (limited value)
	Landscape diversity, structure, and connectivity of patches
	Invasive species cover

tors can be made with relatively little training and the only tools required are a measuring tape and a small compartmentalized box to hold water for the slake test. This permits evaluation of remote sites not accessible by car. For sites with road access, simple single-ring and other infiltration tests (e.g. Dobrowlowski 1994) can be performed. We have also developed a simple, inexpensive soil penetrometer to quantify the level of soil compaction (Herrick *et al.* in preparation)). At the highest level of effort, soil samples can be returned to the laboratory for determination of bulk density and organic matter content, and more precise measurements of texture. Ratios and the magnitude of variation of selected parameters may also serve as useful indicators (Herrick and Whitford 1995). For example, the extent of resource redistribution which has occurred within a system is indicated by the ratio of clay and/or soil organic matter content under vegetation and in bare areas.

Comparisons for Selected Indicators

Of the four indicators displayed, basal cover of long-lived grasses proved to be the most sensitive (Figure 2). It is also a relatively important indicator for integrating inter-annual variability in this system. While the cover of all plant species and, correspondingly, mean bare patch length, vary widely with annual precipitation, the cover of long-lived grasses tends to be somewhat more stable. The relatively small difference in soil stability was due to the insensitivity of the measurement system. The measurement system has been revised since this dataset was collected.

Timing of Measurements

Variability in rangeland soil erosion may be greater within-years than between-years due to seasonal changes in climate, vegetation and litter structure and cover, and the physical characteristics of the soil

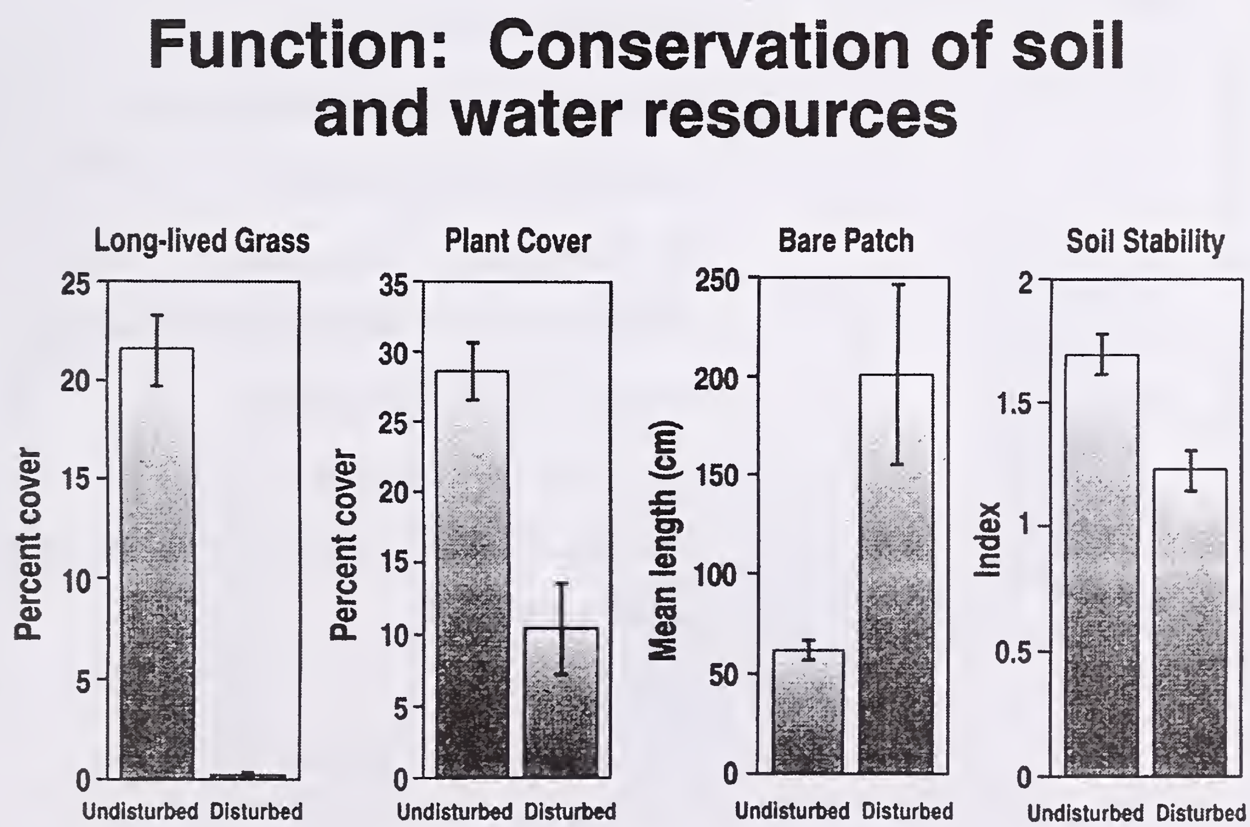


Figure 2. Values for indicators related to the function of conservation of soil and water resources (n = 3 sites; $\pm$1 S.E.).

surface (Blackburn and Pierson, 1994). If measurements can be made at only one time during the year, we suggest that they be made immediately prior to, or at the beginning of, the period the system is most susceptible to resource loss. An indication of when this period occurs may be obtained by examining records of sediment loads in local streams and rivers.

Function 2: Animal Production

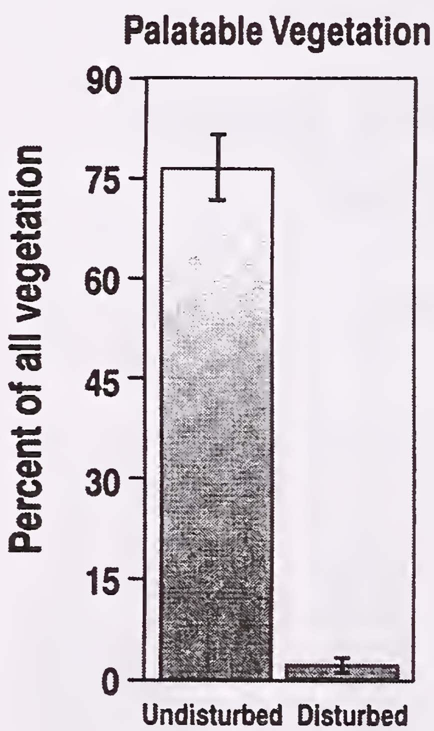
Indicators

The value of an area for animal production depends on the quantity, nutritive value, and palatability of the vegetation at different times of the year. We plan to use a forage value index which combines these three elements (Figure 3). Depending on the availability of soils data, a soil productivity index can be used to dampen interannual fluctuations associated with precipitation. Animal production in the Chihuahuan Desert is currently dominated by cattle raised for beef consumption. Changes in the animal products expected from the land could require the substitution of different indicators, or the assignment of different weights to existing indicators.

Comparisons for Selected Indicators

The proportion of all vegetation which is palatable to cattle at some time during the year (not including mesquite pods and yucca flowers which provide relatively little value per unit area covered) was reduced to near zero in the highly disturbed sites (Figure 3). This corresponds with, but is not identical to, the percent cover of long-lived grass used to assess the function of resource conservation described above, and illustrates how the indicators used for different functions are often based on the same measurements, but are interpreted in slightly different ways.

Function: Animal production



Additional Indicators

- **Soil Productivity Index**
- **Index of Palatability**

  $= \sum_{sp=1}^{s}$ [% cover * (months useable/12) * palatability rating]
- **Index of Forage Value**

  $= \Sigma$[% cover * Index of palatability * nutritive value * biomass rating]

Figure 3. Values for indicators related to the function of animal production (n = 3 sites; ±1 S.E.).

Function 3: Biodiversity Conservation

Indicators

The function of biodiversity conservation is perhaps one of the most difficult to evaluate. Simple species counts and simple diversity indices are useful only as starting points. They cannot be consistently related to ecological condition because high plot species diversity frequently indicates a system in decline due to the increase in diversity associated with the invasion of exotics and disturbance-tolerant species. Diversity may be highest when the system is in an unstable transition state between two or more plant communities. Long-term studies of bird communities in the Chihuahuan Desert show highest diversity on disturbed sites with heterogeneous vegetation and lowest diversity on relatively undisturbed sites with homogenous vegetation (Whitford *et al.* unpublished data). In a related study, ant communities provided no reliably interpretable patterns of composition or diversity over a wide range of disturbances (Whitford *et al.* unpublished data).

Furthermore, many species are difficult, if not impossible, to census. Consequently, indicators of long-term trends in the biodiversity of all taxa are more important than indicators based on point-in-time counts. An example is the percent cover of aggressive exotic species which have the potential to outcompete natives. Finally, in order to assess current and potential long-term patterns in biodiversity, data from plot-level studies should be interpreted, where possible, at the landscape level. This is important both to incorporate the effects of landscape heterogeneity (Forman and Godron 1986) and to predict potential future extinctions based on patch size and edge effects.

Comparisons for Selected Indicators

Native grass cover (Figure 4) was selected for illustration because of its relative sensitivity to disturbance and because it again illustrates the congruence between some indicators for different functions (long-lived grass cover for resource conservation and palatable vegetation for animal production). The num-

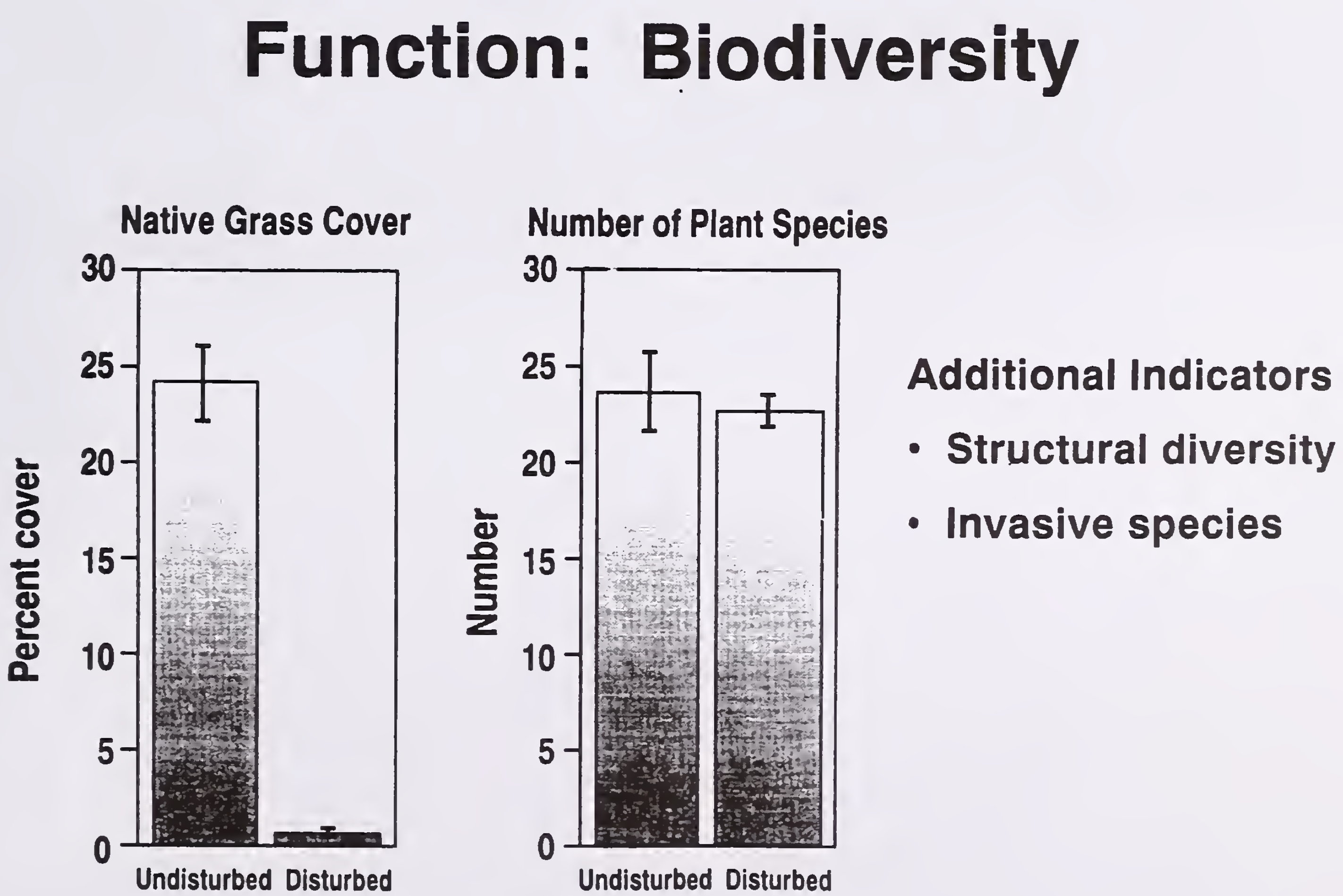


Figure 4. Values for indicators related to the function of biodiversity conservation. Note that number of plant species is not generally a good indicator (see discussion in text) (n = 3 sites; ±1 S.E.).

ber of plant species clearly says little about the status of the system. The disturbed site is dominated by disturbance-tolerant annuals and invasive shrubs, while the relatively undisturbed site has a higher proportion of native perennials.

Combination of Indicators

The procedure for combining the indicators follows Table 1. We are currently in the process of developing scoring functions and weights for these indicators.

APPLICATION TO OTHER ECOSYSTEMS

The four-stage approach to indicator selection and integration described above is equally applicable to forest and agricultural ecosystems. In most cases, however, indicators will need to be changed or adapted for each system, even when the ecosystems perform similar functions. For example, both forest and rangelands are expected to perform many similar functions, and many of the indicators described above for rangelands would also be expected to apply to forests. However, some of the indicators, such as structural diversity, would need to be modified and applied at a different scale, while others, such as perennial grass cover, would be less relevant for mature forested systems.

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Indicadores para Estimar la Densidad Ecológica de Venados en el Noreste de México

Dr. Alfonso Martínez Muñoz[1]

Densidad ecológica de una población es la relación que guarda el numero de animales con la cantidad y calidad de los recursos disponibles en el hábitat. La densidad ecológica puede ser determinada mediante el conteo de los animales, y la comparación de su número con la disponibilidad de nutrientes, espacio, y cobertura del ecosistema. Estas evaluaciones resultan a menudo complejas y demandan gran inversión. Para evitar estas evaluaciones es posible utilizar indicadores tanto de animales como de su hábitat. Los indicadores que han sido y están siendo utilizados en poblaciones de venado cola blanca texano (*Odocoileus virginiaus texanus*), venado bura del desierto (*Odocolieus hemionus crooki*) en el noreste de México son: a) relación entre edad y peso b) relación entre peso y medidas corporales, c) concentración en suero de tiroxina (T_4), trijodotironina (T_3) y urea nitrogenada, y d) estructura poblacional. Los parámetros del hábitat de estas especies utilizados son: a) relación entre las especies deseables, menos deseables e invasoras, y b) grado de utilización de las especies vegetales más palatables. En el presente escrito se presentan resultados de los parámetros utilizados, se discuten las ventajas y desventajas de cada uno.

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Indicators to Estimate the Ecological Density of Deer in Northeast Mexico's

Alfonso Martínez Muñoz[1]

Ecological density of a population is the number of animals relative to the quantity and quality of habitat resources available in the habitat. It is seldom feasible to evaluate ecological density by censuring the population and measuring all pertinent factors of its habitat. However, indices of ecological density can be obtained from the population or from the habitat. The indicators that has been used in the population of white-tailed deer (*Odocoileus virginianus texanus*) and desert mule deer (*Odocoileus hemionus crooki*) are population-condition indices and habitat-condition indices. The population-condition indices are: a) relations among age and weight, b) relations between weight and body size, c) concentration in serum of tiroxine (T_4), triiodothyronine (T_3) and urea, and d) determination of age pyramids. The habitats-condition indices are: a) determination of range trend by observing changes in the abundance of increaser, decreaser and invader species, and b) determination of the grad of utilization of preferred species. In this paper will be present results of the used indicators as well as a discussion of the advantages and disadvantages of each one.

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Some Statistical Considerations for Environmental Monitoring

Fernando Avila[1]

Abstract.—In this paper we discuss the role of statistics in the process of environmental monitoring. The objective is to clarify general concepts with no intention of engaging in technical details, and to provide a comparison of design and statistical approaches.

THE MONITORING PROCESS

We define *monitoring* as the collection of direct measurements of the environment and *environmental monitoring* as the determination of the presence or absence, and the identification, of contaminants in a region. We define five stages of a monitoring program: *sampling design, sampling, laboratory analysis, statistical analysis and decision making*.

All information gathering, processing, and dissemination activities used to support a monitoring program is called a *network*. The establishment of criteria to select appropriate monitoring locations, parameters, sampling frequencies and statistical and analytical methodology based on predefined specific objectives is called a *network design*. The primary factor to consider in network design is use of data. Data is useful only if it is collected to serve an objective, for example, the main objective of collecting hydrologic data is to provide information for assessing, developing and managing the water resources of a region or a country. The ideal network incorporates the information concerning the hydrological processes into a framework that accounts for the effects that the data will have on future actions of the decision makers.

We distinguish two types of networks according to the objectives of the program. A *monitoring network* is a systematic means of acquiring and analyzing data which is planned and has some measure of continuity. A *sampling network* is an arrangement of sites or tracks in space and time at which parameters are measured over a specific time period to provide data necessary for a given objective.

Statistics is useful not only for sampling design and data analysis. It can also be an integral part of the mathematical models that will be used to provide an answer to concrete problems. Take, for example, the solution to two environmental issues concerning groundwater contamination: *groundwater monitoring of suspected contaminated sites*, where a procedure is needed that will yield a probability of plume intercept for a plume originated at the suspected source location, and *groundwater remediation of sites identified as contaminated*, where a procedure is needed that will adjust pumping schedules to optimize remediation as a function of time, cost and other variables. In both cases it is assumed that there is enough knowledge of the aquifer parameters that determine groundwater behavior. However, the determination of parameters, given limited information of the groundwater behavior, the so called *inverse problem*, is an ill-posed problem that has to be solved statistically (O'Sullivan, 1986; Fradkin and Dokter, 1987; Loaiciga and Mariño, 1987).

DATA ANALYSIS

The statistical analysis of data obtained from a monitoring program should take into account their spatial characteristics (non-replicability, sampling support, spatial correlation), their temporal characteristics (replicability, sampling support, temporal correlation) and quantitative characteristics (level of

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detection, level of quantification, censoring) and the scale (local or regional) at which the problem is being analyzed.

An important feature of environmental data is that they are obtained from sampling the Earth. *Spatial data* are measurements and/or observations of one or more attributes taken at specific locations, in other words, they are data with a geographical reference. The spatial organization of the data is a key property for further analysis. *Spatial data analysis* is the set of techniques design to support a spatial perspective of the data. Its results depend on the location of the objects or events being analyzed, and require both the "coordinates" and the attributes of the objects or events. The techniques can be classified in two types: *analysis of spatial distributions* and *analysis of the spatial variation* of one or more attributes.

A *Geographical Information System (GIS)* is a data base containing a discrete representation of a geographical reality, in the form of a two-dimensional geometrical object with attributes attached to them. They are very useful or extracting and displaying spatial data but they are deficient in their capacity of developing hypothesis about them. The integration of a GIS and spatial data analysis is a current research topic with a high potential for applications in environmental studies (Haining, 1990, Goodchild et al., 1992; Haslett, 1992; Griffith, 1993).

STATISTICAL MODELS AND PARADIGMS

Statistical models can be used for different purposes: to detect the presence or absence of pollutants, to determine the concentration of pollutants, to quantify the degradation of the environment, to evaluate policies and to rank remediation programs. The end product of a statistical analysis can be a measure of the reliability of a map, a measure (*index*) of the ecological condition, or a measure (*trend*) of the continuity of the ecological condition.

Let Z be an ecological attribute. The choice between a deterministic description or a stochastic model is an important decision of the modeler. This choice depends on the objectives of the program and the different practices and attitudes across environmental disciplines. Depending on the (non-provable) hypothesis about the "nature" of Z, we will have two different *statistical paradigms*.

If Z is modeled as a random function, then we are talking about *model based inference*, where the predictor of Z, or of a transformation of Z, is based upon a probabilistic structure built into the model space of Z. This is the way of *geostatistics* (Matheron, 1971), where usually random noise is not added to the data.

If Z is modeled as a deterministic function, but measurements are taken at locations chosen by random sampling, the estimation of Z, or of a functional of Z, is based upon the probability structure given by the sampling design. This would be an example of a *design based inference*. In this type of inference, random noise is a product of the measurement process and a nuisance term that gets "filtered out" by a choice of design and estimator.

There have been some discussions about the merits of the two ways of thinking (Särndal, 1978; Hansen, Madow and Tepping, 1985; de Gruijter and ter Braak, 1990; Brus and De Gruijter, 1993). Design based methodologies have provided the foundation for inferential studies and have recently been applied to the sampling of natural resources, forming the statistical basis of the EMAP program (Messer, Linthurst and Overton, 1991; Stevens, 1993; Overton and Stehman, 1995). Statistical analysis based on models have provided a way to incorporate change of support issues (Cressie, 1993), have introduced the notion of spatial correlation as a fundamental concept, and have provided solutions to network design problems (Cressie, 1993).

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Ecological Quality Assurance: A Canadian Perspective

John Lawrence[1] and Craig Palmer[2]

Abstract.—Ecological quality assurance in Canada largely evolved from the Canadian component of the Canada/United States Long Range Transport of Air Pollutants Program (LRTAP) from 1982 - 1990. Highlights of the history, accomplishments and short comings of the quality assurance programs of the aquatic, atmospheric and terrestrial components of the LRTAP program are discussed, including essential elements of site selection, sampling methodology, analytical methodology, data management, network comparability and laboratory performance.

Quality assurance workshops were held annually to discuss issues and concerns of common interest as well as to provide a forum for discussion of broader issues such as total quality management and data quality objectives. It is recommended that these workshops continue and that they become a focus for collaboration on data quality issues among the NAFTA partners.

INTRODUCTION

Human Society is today facing more serious environmental problems than ever before. These problems, many of which are just becoming evident, are very much more complex and of a larger scale than those experienced previously. National and global scale ecological issues such as climate change, UV-B, long range transport of persistent organic pollutants and large scale detrimental land management practices have added a new dimension to previous, more local, concerns about pollution of air, water and land (Barica 1995). Table 1 shows some examples of the large scale ecological issues facing society today. Traditional approaches to collecting data for environmental decision making are not adequate to address the types of questions posed by these larger concerns. In order to evaluate the extent and consequences of various human impacts on natural systems, environmental managers need the type of information that only broader scale, longer term ecological monitoring can provide (Palmer and Peck 1995).

Table 1. Examples of Large Scale Ecological Issues.

Climate Change
Long Range Transport
Large Scale Detrimental Land Practices
Biodiversity
Water Quantity & Quality
Population Explosion
Introduction of Exotic Species
Waste Disposal

Canada, the United States and Mexico are each presently developing a large scale program for monitoring ecological assessment of terrestrial and aquatic ecosystems. It is appropriate, therefore, to share our knowledge and adopt a consistent approach throughout the three countries. Nowhere is this more important than in the area of ecological data quality assurance. It is highly probable that in the very near future the three countries will want to combine their data

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sets into a single North American data base or will want to combine data from separate data bases for continent wide interpretation and decision making. According to the North American Commission for Environmental Cooperation, (NACEC 1995), one of the most serious impediments to cooperation among the partners is the lack of standardized data. Now is the time to consider a more international approach to data quality issues.

In the last 15-20 years, quality assurance (QA) principles have been invaluable when applied to environmental data collection programs. During this time, agencies involved in the collection and analysis of chemical data developed some sound QA practices and implemented them in rigorous QA programs. Implementation of a QA program can help ensure that the data being collected meet pre-defined standards of quality with a stated level of confidence and that the data will be reliable, compatible and appropriate to the needs of the user.

However, new and greater challenges towards the implementation of QA objectives and practices are presented by large scale, long term ecological monitoring programs (Palmer and Peck 1995). The overall size of these programs severely complicates logistical operations for data collection and information management procedures. Variability can be difficult to deal with on a local scale but this difficulty is compounded many times at regional, national and global scales. It is also difficult to deal with the inherent biological variation in natural systems. The nature of the questions asked, the measurements made and the assessments requested of these programs severely complicates the planning and design aspects of ecological monitoring programs. Detection of ecological trends, many of which are extremely subtle, requires a commitment by agencies of adequate resources for long term programs.

The purpose of this paper is to review QA practices developed in Canada that are appropriate for large scale ecological monitoring programs. Many of these practices evolved from the Canadian component of the Canada/United States Long Range Transport of Air Pollutants (LRTAP) program between 1982 and 1990. The paper will also discuss these practices in terms of the current concept of total quality management.

REVIEW OF CANADIAN LRTAP QUALITY ASSURANCE PROGRAM

In 1982, Canada and the United States signed a Memorandum of Intent that addressed long range transport of air pollutants (Environment Canada 1982). In this memorandum, the key issue was the acid loadings to both countries. It was noted at that time that Canada and the United States were producing significantly different loading information and, in addition, various researchers questioned the reliability of much of the data collected prior to 1980.

The Canadian Research and Monitoring Coordinating Committee (RMCC) established a number of working groups to address the atmospheric, surface water and terrestrial impacts of acidic pollutants. The members of RMCC recognized the need for a well designed QA program to support the research and monitoring of the LRTAP program and established a separate working group to address and promote QA and to ensure that good science was part of every study in the LRTAP program. The key roles of the QA working group are listed in Table 2.

This section charts the history, accomplishments and some of the short comings of the QA program. All studies involving quantifiable and semi- rigid analytical, sampling and data based procedures incorporated comprehensive QA protocols. With a few exceptions, the same degree of rigor could not be applied when dealing with the response of biological systems and semi-quantitative sampling protocols. As a result of previous experience, the atmospheric and aquatic components of the program had a clear lead in the implementation of QA and as a result, the measurement process for these studies was more thoroughly addressed. In as much as the terrestrial studies tended to have a greater ecological compo-

Table 2. The Role of the Canadian LRTAP Quality Assurance Working Group

To Foster Appropriate Quality Assurance Protocols
To Foster Comparability of Data
- Siting and Sampling Guides
- Analytical Methods Guides
- Round-Robin Laboratory Studies
- Network Intercomparisons
- Data Base Guides
Point of Contact with U.S. Counterparts

nent, advanced QA techniques to support such monitoring and research were developed gradually during the course of the program.

Aquatic Effects Studies

The purpose of the aquatic effects studies for the Canadian LRTAP program was to examine changes over time in the aquatic chemistry and biota due to the long range transport of air pollutants with particular focus on acid precipitation (RMCC 1986). The work was undertaken through numerous federal and provincial government agencies. In many cases, the research evolved out of previous work or was built into ongoing aquatic studies. Some compromise was needed in the study design since the detection of temporal trends at a particular site is not based on the same statistical characteristics as those for determining spatial evolution of surface water quality.

In many cases, historical data bases as well as current data were used. As a result, a single QA management plan or document outlining the QA procedures did not exist. Some of the QA protocols were established for previous or other water monitoring programs and were retained, evaluated and continually updated for the LRTAP program. Documentation was available but was scattered throughout a number of published and unpublished documents which reflects the diverse background of the research and monitoring activities. This documentation included established siting criteria, sampling and shipping protocols as well as analytical criteria.. Data validation techniques employed included ion balance routines, mass balance measurements (theoretical vs. measured dissolved solids), theoretical specific conductance calculations. It was also recognized that most of those criteria fail in the case of low ionic strength waters that contain significant quantities of organic acids.

Accuracy, precision, representativeness and completeness of the data were monitored through field and laboratory QC programs (RMCC 1990a). These included siting criteria, field blanks, field replicate sampling (spatial and temporal), split samples, blind audit samples, standard additions, and laboratory QC encompassing within-run and between-run replicate samples, calibration standards and checks, laboratory intercomparison samples, known reference samples, method blanks and interference, sensitivity and recovery checks. The number of samples and sampling frequency required for a particular study were derived statistically (Yan 1986).

Data validation techniques were especially important to ensure complete and representative data sets. Dealing with "less than" values and the possibility of eliminating anomalous data which in fact are real were problems which were crucial to the integrity of the data base. All Canadian researchers used a stringent set of data screening techniques for the inclusion or exclusion of data. Data slated for exclusion were always checked manually prior to their elimination.

Overall, the quality assurance protocols used in the LRTAP aquatic studies proved effective to support the program and met individual project objectives.

Atmospheric Effects Studies

From the late 1970s to the late 1980s, atmospheric research into the long range transport of air pollutants focussed on three atmospheric processes - transport, conversion and deposition (RMCC 1990b). By far the largest effort was concentrated on the measurement of regional precipitation chemistry and wet deposition. To this end, the government of Canada and most provincial governments installed wet deposition monitoring networks within their jurisdictions (see Table 3). The effort spent on other atmospheric measurements, e.g. regional air chemistry, dry deposition, fog/cloud water deposition was also significant but less so than on the network measurements of wet deposition. The atmospheric research community has expended considerable effort on quality control of these networks; mostly in quantifying the accuracy, precision, comparability, completeness and representativeness of wet deposition measurements (RMCC 1990a). Some of the specific QA activities undertaken as part of the atmospheric effects program include:

- the upgrade of several federal and provincial wet deposition monitoring networks to improve siting and operations;
- the development and implementation of formal QA programs within existing deposition monitoring networks;

Table 3. Canadian Wet Deposition Monitoring Networks.

Network Acronym	Network Name	Operating Period
CANSAP	Canadian Network for Sampling Precipitation	1977 - 1983
APN	Canadian Air and Precipitation Network	1978 - 1983
CAPMoN	Canadian Air and Precipitation Monitoring Network	1983 - present
BCPCSN	British Columbia Precipitation Chemistry Sampling Network	1984 - present
APQMP	Alberta Precipitation Quality Monitoring Program	1978 - present
MAPMN	Manitoba Acid Precipitation Monitoring Network	1984 - 1986
APIOS - C	Acidic Precipitation in Ontario Study - Cumulative Network	1980 - present
APIOS - D	Acidic Precipitation in Ontario Study - Daily Network	1980 - present
REPQ	Réseau d'échantillonnage des précipitation du Québec	1981 - present
NBPN	New Brunswick Precipitation Network	1981 - present
NSPMN	Nova Scotia Precipitation Monitoring Network	1980 - present
NPMN	Newfoundland Precipitation Monitoring Network	1987 - present
EPSN	Environmental Protection Service Network	1981 - present
GLPN	Great Lakes Precipitation Network	1969 - present

- the operation of intercomparison studies between federal and provincial networks, and between Canadian and US networks, including both instrument and network intercomparisons;
- the operation of laboratory intercomparison studies between federal, provincial and US laboratories involved in wet and dry deposition research;
- the development of standard methods for, a) calculating wet deposition from precipitation chemistry data, and b) evaluating the representativeness of wet deposition measurements based on data completeness statistics and site representativeness ratings.

Figure 1 shows the ratio of annual precipitation-weighted mean sulphate concentrations at collocated provincial and federal (CAPMoN) sites for 1984, 1985 and 1986. As can be seen from Figure 1 and Table 4 (Vet et al 1989), the results of network intercomparisons indicate that wet deposition of the major acidifying species can be measured quite precisely (differences typically less than 5%) and with good comparability (within 25% between networks). Throughout the decade, site representativeness improved in many of the Canadian networks and data completeness has become an important factor in assessing the quality of wet deposition data.

Terrestrial Effects Studies

Quality assurance for the terrestrial effects component of the Canadian acid rain program did not have the same profile as for the aquatic and atmospheric components. Most terrestrial studies, and particularly the later ones, have incorporated features associated with QA, including formal quality assurance plans, field manuals, duplicate sampling, collocation of sampling equipment, field training, pilot studies, laboratory control programs and interlaboratory comparisons. However, some QA

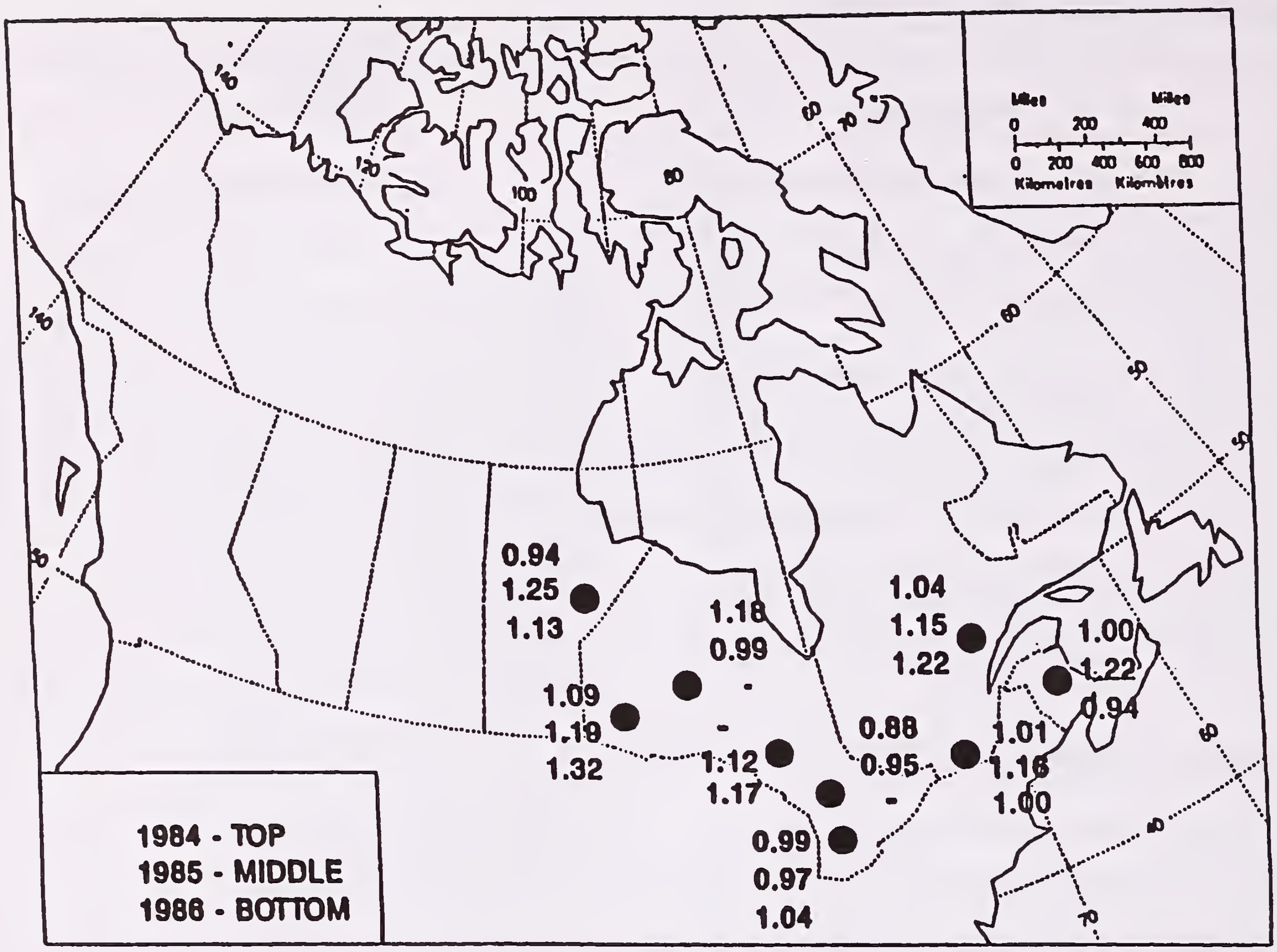

Figure 1. Ratios (Province/CAPMoN) of annual precipitation-weighted mean sulphate concentration at collocated provincial and CAPMoN sites for years 1984 (top), 1985 (middle) and 1986 (bottom).

Table 4. Estimates Of Bias Between CAPMoN And NADP/NTN Precipitation Chemistry Measurements (From Vet et al, 1989)

Measurement	Between-Network Bias	
	Sutton, Quebec	Penn State University Scotia, PA.
SO_4^{--}	-0.04	0.02
$N\text{-}NO_3^-$	0.01	0.04
Cl^-	-0.02	0.00
Ca^{++}	0.00	0.01
$N\text{-}NH_4^+$	0.05	0.05
Mg^{++}	0.00	0.00
Na^+	-0.02	-0.02
K^+	0.00	0.01
H_3O^+	0.007	0.008
pH	-0.08	-0.06
Standard Gauge Depth (mm)	1.72	1.0
Sample Depth (mm)	2.6	2.0

Units in mg/1 except pH, sample depth and standard gauge depth.

components were implemented after study commencement or were considered only informally. Although there are notable exceptions, much of the documentation associated with terrestrial monitoring studies existed only in draft form.

In 1987, the Quality Assurance Working Group began to promote awareness of the need for upgrading the QA in terrestrial monitoring studies. This included preparation of standard methods manuals for analytical procedures for commonly measures parameters and for field sampling practices (Schumacher et al 1995). A laboratory intercomparison study was also established. This encouraged many of the participating laboratories to adopt internal QA/QC programs and formal QA/QC plans.

Collocation of sampling within a given project was found to be absolutely essential for assessment of field precision in data collection. Frequently, sampling plots were collocated between agencies, enabling direct comparison of results. By way of examples, the Turkey Lakes Watershed study made use of collocation of both sampling and sampling equipment whereas the North American Maple Decline Project did not collocate sampling efforts within the study but adjacent states and provinces evaluated plots in adjoining jurisdictions (RMCC 1990a).

The determination of accuracy in field sampling is very difficult due to the lack of appropriate standards with which to compare field measurements. Nevertheless, there have been attempts to measure the accuracy of field measurements such as by comparison with alternative methods for measuring field parameters (e.g. the Fundy Birch Deterioration Project compared active and passive fog collection, calibration of biomonitoring with collocated monitors and comparison of percent leaf injury assessed by subjective and quasi-objective techniques). There was also the need to address the biases associated with observation and measurement between field technicians. The assessment of the health and vigour of tree crowns is particularly subject to observer bias. The Ministry of Environment for Ontario did extensive testing of the reproducibility of the Numerical Decline Index Rating System in the field within and between evaluators (McLaughlin et al 1988).

In summary, many of the measurements of the terrestrial effects studies require judgemental observations. In order to improve reliability, it is necessary to develop new and appropriate techniques. These would include the use of multiple observers and specially trained observers.

Quality Assurance in Laboratory Studies

The external QA program presented to the LRTAP community by the Quality Assurance Working Group primarily addressed issues in the laboratory measurement process. In this area the program has excelled and has had a positive impact. The availability of one study every four months for over ten years has provided the analysts and laboratory managers with an atmosphere conducive to improvement and generated a heightened awareness of QA issues. Evidence provided in each study has illustrated how many laboratories have clearly improved. Comparability of U.S. and Canadian data is also excellent (RMCC 1990a).

When the QA program was initiated in 1982, a data base management system was adopted to archive all pertinent information. It now contains over half a million laboratory results and is an extremely valuable resource (Aspila 1995). The associated software has been instrumental in a) creating laboratory specific performance appraisals, b) demonstrating the long term stability of natural water samples and c) illustrating the ongoing performance of each laboratory on a specific or group parameter basis. An illustration of how a typical laboratory's performance improves with increasing participation in the program is shown in Figures 2 and 3. The data base can be used to illustrate how precision varies as a function of concentration. Specific criteria on performance specifications for future studies can now be set. Although the external QA program has been effective, further areas need to be addressed, including a) the monitoring of field sample variances, b) the discernment of laboratory measurement bias on a more absolute basis, and c) more frequent studies on terrestrial substrates.

Summary of LRTAP Quality Assurance Activities

The Quality Assurance Working Group ensured that the data generated for the Canadian acid rain program had, for the most part, sufficient credibility to allow target acid loading estimates to be calculated. In summary the working group:

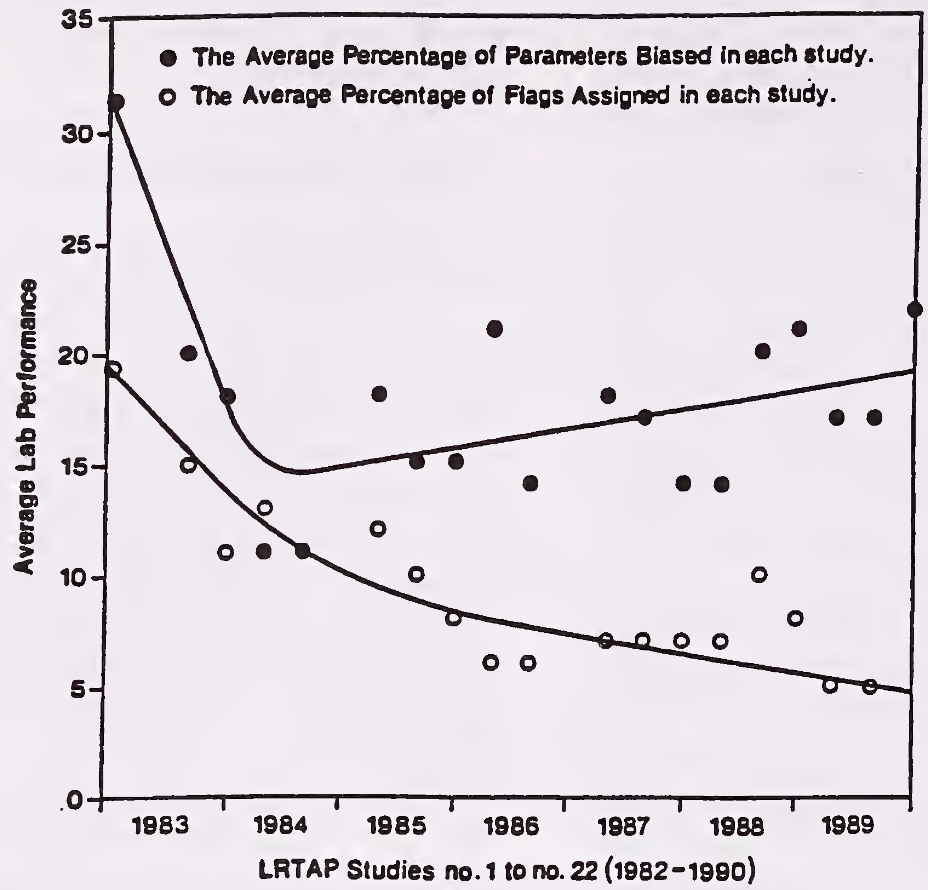

Figure 2. Typical impact of continued participation in an external quality assurance program on laboratory bias and flag frequency.

- was instrumental in developing the proposed siting, sampling and data reporting protocols for all studies;
- maintained close liaison with all studies in order to verify the adequate implementation of quality assurance procedures;
- was instrumental in creating strong links with colleagues in the U.S. A number of joint efforts were organized including, analysts workshops, development of QA guidelines for the Eulerian Model Evaluation Field study and a series of ecological quality assurance workshops.

ECOLOGICAL QUALITY ASSURANCE WORKSHOPS

Under the auspices of the Quality Assurance Working Group, annual joint Canada/U.S. ecological QA workshops were held in Denver (US-EPA 1988), Las Vegas (US-EPA 1989), Burlington (Environment Canada 1990), Cincinnati (US-EPA 1991) and Toronto (Environment Canada 1992). The workshops discussed advances in QA concepts such as total quality management, data quality objectives and the extension of conventional analytical QA principles to ecological monitoring. Many of these concepts are now becoming standard practice in comprehensive ecological QA programs.

Total Quality Management

The application of total quality management, TQM, is a recent development in quality assurance for ecological monitoring. TQM implies that the monitoring program in its entirety must be stringently controlled. This means that not only each step in the measurement process but the linkages between them and the overall purpose should adhere to well prescribed quality guidelines. The concepts of TQM include a focus for defining quality in terms of meeting clients needs, involving the expertise of all personnel, enhancing communication, having a

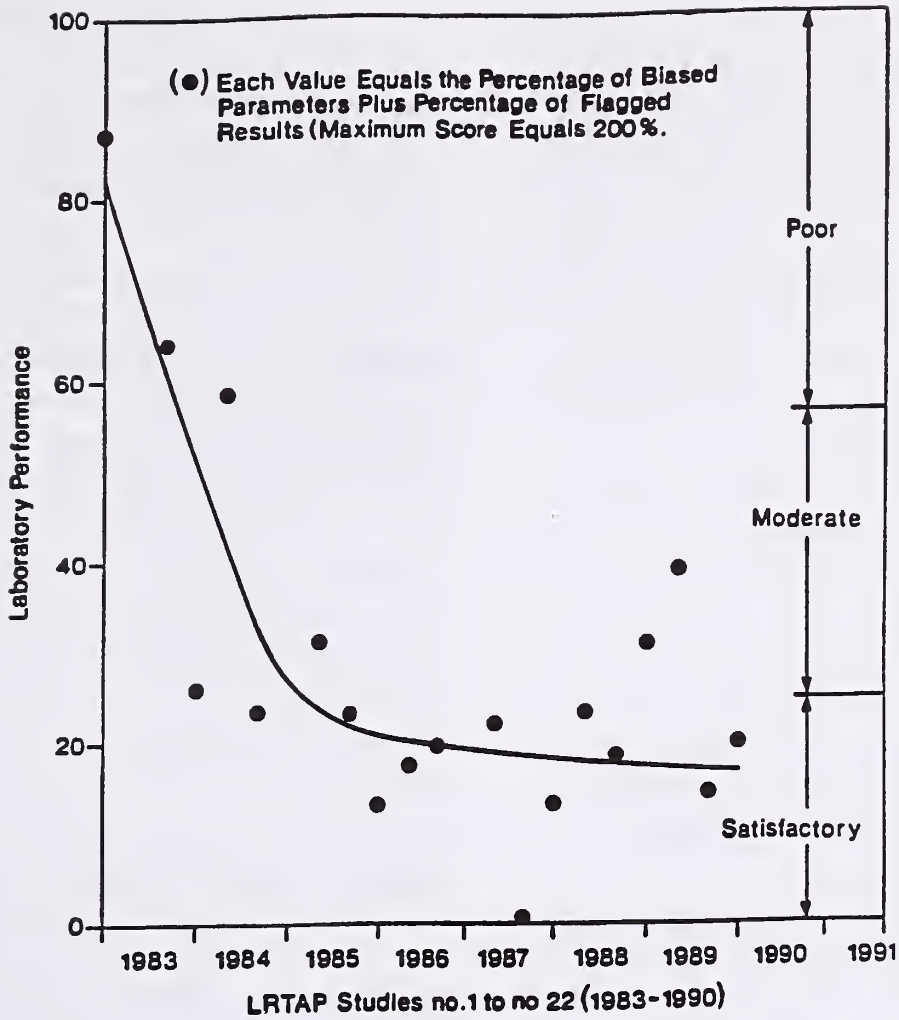

Figure 3. Typical impact of continued participation in an external quality assurance program on overall laboratory performance.

philosophy of continual improvement and having continual commitment from management (Palmer and Peck 1995).

The manufacturing and service industries have successfully applied TQM for some time but it has only recently been applied to large scale ecological monitoring programs. Because of the complexity of these programs, the application of TQM has not been a simple task. TQM principles are not well understood by ecological scientists, partly because they have not been widely used in the past and partly because the terminology used differs between scientists and industry. Many of the concepts are difficult to apply in an ecological monitoring system due to specific attributes of this type of data collection.

Some of the principles of TQM applied to ecological monitoring include improving communication linkages between field crews, conducting debriefing sessions to obtain ideas from field crews, including the indicator specialists, in the development of QA plans, involving management in planning, review and budgeting of QA tasks, and conducting information needs workshops with potential clients of the monitoring information.

One of the challenges has been to obtain feedback on data quality issues in a timely manner. Samples taken in the field often take several months to be processed by analytical laboratories. Often, results from these analyses come too late to be used in the planning and improvement for the next field season.

Data Quality Objectives

Rather than rely on chance that collected data from a monitoring program will provide the necessary information to address the study objectives, the concept of establishing data quality objectives, DQOs, is receiving increasing attention (Brantly and Michael 1989; Neptune and Blacker 1990). DQOs serve to improve communication among the people responsible for designing, implementing and

interpreting the data from monitoring programs and more specifically, to produce the qualitative and quantitative specifications for the collection of the required data. Data quality objectives provide an estimate of the maximum degree of uncertainty that can be tolerated in a data set for a given program. The process of developing DQOs serves four essential functions:

- establishes communication between decision makers, technical personnel and statisticians (data interpreters);
- provides a mechanism by which many objectives of a monitoring program can be reduced to one or more critical issues;
- facilitates the development of clear statements of program objectives and the data that are needed to satisfy those objectives;
- provides a structure in which an iterative process of guidance, design and feedback may be accomplished.

The DQO process depends upon the early and continued involvement of the decision maker: the person who must eventually rely on conclusions derived from the data to choose among courses of action to address a specific problem. These courses of action may involve major undertakings that could impact large groups of society and cost millions of dollars. The decision makers role is to define the decisions, objectives or management questions for which the data are thought to be needed and to specify the degree of confidence required to answer those questions unambiguously. The technical experts and statisticians have two roles: first to help the decision maker examine and refine the proposed objectives of the monitoring program until all parties share a common understanding of a limited, narrowly defined set of questions to be answered; and secondly, to design a sampling and analysis scheme that will produce data of the type and quality required to answer the questions posed with the required degree of certainty.

The DQO process is an iterative series of steps which, when completed, produces the following specifications for a monitoring program:

- a clear statement of program objectives;
- a clear list of data requirements to address the objectives;
- a description of the spatial and temporal boundaries of the area to be sampled;
- a clear statement of the data interpretation techniques to be used;
- a clear statement of the performance criteria required of the data.

With all this information, the technical experts and statisticians can design an optimal sampling and analysis plan that will produce the right data with a sufficient degree of confidence to resolve the program objective(s). Frequently, there are not enough resources available to collect the required data or the underlying methodology may not be fully developed to achieve these data quality requirements. In such cases a degree of compromise is necessary and the researchers have to decide between adding more resources, taking time to advance the methodology or to ease off on the data quality criteria. Whichever approach is taken, it must be with the full agreement of the decision maker and the research and technical team.

CONCLUSIONS AND RECOMMENDATIONS

The QA approach developed and used for the LRTAP program proved invaluable to decision makers in calculating target loadings, monitoring to determine if targets have been met and for temporal and spatial trend assessment. Ecological QA is still in its infancy and needs to be further refined to fully encompass the principles of total quality management and data quality objectives. There is a window of opportunity for the three NAFTA partners to do this collectively in the coming months and years.

It is recommended that:

1) The three countries work together, under the auspices of the North American Commission for Environmental Cooperation, to develop a standardized approach to quality assurance for ecological monitoring;
2) The series of ecological QA workshops continue and be broadened to include all three countries;
3) The three countries immediately start to use common standards and participate in field and laboratory intercomparison studies;
4) Tri-partite ecological monitoring workshops, like the present one, be held on a regular basis to monitor progress in collaboration.

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Quality Assurance in Long Term Coastal Monitoring

Adriana Y. Cantillo[1]

Abstract.--The NOAA National Status and Trends (NS&T) Program determines the current status of, and changes over time in the environmental health of US estuarine and coastal waters. Concentrations of organic and inorganic contaminants are determined in bivalves, bottom-dwelling fish and sediments. The quality of the analytical data generated by the NS&T Program is overseen by the performance-based Quality Assurance Project. This Project has been in operation since 1985 and is designed to document sampling protocols, analytical procedures and laboratory performance, and to reduce intralaboratory and interlaboratory variation. In addition, the QA Project will facilitate comparisons among different monitoring programs with similar QA activities and thus extend the temporal and spatial scale of such programs. To document laboratory expertise, the QA Project requires that all NS&T laboratories participate in a continuing series of intercomparison exercises utilizing a variety of materials. The organic analytical intercomparison exercises are coordinated by the National Institute of Standards and Technology, and the inorganic exercises by the National Research Council of Canada.

INTRODUCTION

In response to the need for information on effects of human activities on environmental quality in coastal and estuarine areas, and the need to develop management strategies to deal with these conditions, the National Oceanic and Atmospheric Administration (NOAA) initiated, in 1984, the National Status and Trends (NS&T) Program for Marine Environmental Quality. The purpose of this program is to determine the current status and detect changes in the environmental quality of our Nation's estuarine and coastal waters. The NS&T Quality Assurance (QA) Project is one of the seven components of the Program and applies to the two monitoring projects: the National Benthic Surveillance Project (NBSP) and the Mussel Watch Project (MWP).

The NBSP collects and analyzes benthic fish and sediments from sites around the coastal and estuarine United States, including Alaska. This effort has been performed primarily by NOAA's National Marine Fisheries Service. The MWP collects and analyzes bivalve mollusks and associated sediments from around the United States, including the Great Lakes, Alaska, Hawaii, and Puerto Rico. This effort is administered by NOAA, with collection and analyses being performed under contract. From 1986 through 1994, the Geochemical and Environmental Research Group, Texas A&M University, College Station, TX, collected and analyzed samples from the Gulf Coast. During this time, Battelle Memorial Institute, Duxbury, MA, and Sequim, WA, collected and analyzed samples from the U.S. East and West Coasts, including sites in the Hawaiian Islands and Alaska. During 1986 - 1989, samples from along the California and Hawaiian coasts were collected and analyzed by Science Applications International Corporation, Inc. The analytes

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include 24 polycyclic aromatic hydrocarbons, 20 polychlorinated biphenyl congeners, DDT and its metabolites, 9 other chlorinated pesticides, organotins, 5 major elements, and 12 trace elements (Table 1). Sampling sites are described in Lauenstein *et al.* (1993).

QUALITY ASSURANCE PROJECT

The QA Project of the NS&T Program assures that despite differences in the analytical methodologies used, data are comparable between all participating laboratories. Details of the QA Project can be found in Cantillo and Lauenstein (1993). The QA Project is not limited to NS&T Program laboratories, but is made available to other laboratories quantifying estuarine and coastal contamination. Since 1990, the Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program - Estuaries (EMAP-E) has been a cosponsor and contributor to the QA Project.

Table 1. Organic contaminants, and major and trace elements determined as part of the NOAA National Status and Trends Program.

Polycyclic aromatic hydrocarbons	High molecular weight PAHs (4-, 5-, and 6-rings)
Low molecular weight PAHs (2- and 3-ring structures)	
	Alkylated chrysene
	Alkylated dibenzothiophene
1-Methylnaphthalene	Alkylated fluoranthene and pyrene
1-Methylphenanthrene	Benz[*a*]anthracene
2-Methylnaphthalene	Benzo[*a*]pyrene
2,6-Dimethylnaphthalene	Benzo[*b*]fluoranthene
1,6,7-Trimethylnaphthalene	Benzo[*e*]pyrene
Acenaphthene	Benzo[*ghi*]perylene
Acenaphthylene	Benzo[*k*]fluoranthene
Anthracene	Chrysene
Biphenyl	Dibenz[*a,h*]anthracene
Fluorene	Dibenzothiophene
Naphthalene	Fluoranthene
Phenanthrene	Indeno[1,2,3-*cd*]pyrene
Alkylated fluorene	Perylene
Alkylated naphthalenes	Pyrene
Alkylated phenanthrene	
Chlorinated pesticides	Polychlorinated biphenyl congeners (IUPAC numbering system)
2,4'-DDD, 4,4'-DDD	
2,4'-DDE, 4,4'-DDE	PCB 8, PCB 18, PCB 28, PCB 44, PCB 52, PCB 66, PCB 77(110), PCB 101, PCB 105, PCB 118, PCB 126, PCB 128, PCB 138, PCB 153, PCB 170, PCB 180, PCB 187, PCB 195, PCB 206, PCB 209
2,4'-DDT, 4,4'-DDT	
Aldrin	
alpha-Hexachlorohexane	
beta-Hexachlorohexane	
Chlorpyrifos	
cis-Chlordane	
cis-Nonachlor	
delta-Hexachlorohexane	Major and trace elements
Dieldrin	
Endosulfan-I	Al, Si, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Sn, Sb, Ag, Cd, Hg, Tl, Pb
Endosulfan-II	
gamma-Hexachlorohexane	
Heptachlor	
Heptachlor epoxide	Organotin species
Hexachlorobenzene	
Mirex	Monobutyltin trichloride, dibutyltin dichloride, tributyltin chloride, tetrabutyltin
Oxychlordane	
trans-Nonachlor	

The NS&T Program does not prescribe specific analytical methods but encourages the use of state-of-the-art procedures. This allows the use of new or improved analytical methodology or instrumentation without compromising the quality of the data sets. It also encourages the contractor laboratories to use the most cost-effective methodology while generating data of documented quality. The methods used by the various laboratories contributing to the NS&T monitoring effort have been documented by Lauenstein and Cantillo (1993). All NS&T laboratories are required to participate in a continuing series of intercomparison exercises utilizing a variety of solutions and natural matrix materials. The organic analytical intercomparison exercises are coordinated by the National Institute of Standards and Technology (NIST), and the inorganic exercises by National Research Council (NRC) of Canada. The analysis of reference materials, such as the NRC Certified Reference Materials (CRMs) and NIST Standard Reference Materials (SRMs), and of control materials generated for use by NS&T labs as part of the sample stream, is required. A minimum of 8% of the organic analytical sample string consists of blanks, reference or control materials, duplicates, and spike matrix samples. The use of control materials does not entirely replace the use of duplicates and spiked matrix samples. A minimum of 2% of the standard inorganic sample string consists of calibration materials and reference or control materials. Analytical data from all control materials and all matrix reference materials are reported to the NS&T Program office. These data are stored in the NS&T Program office.

In NS&T trace organic analytical procedures, internal standards are added at the start of the analytical procedure, specifically at the sample homogenization step, and carried through the extraction, cleanup and instrumental analysis. The internal standards, when taken through the extraction and clean-up steps and then used for quantification, account for analyte losses. Acceptable recovery rates

must be higher than 50%. Analysts are responsible for monitoring recovery rates and determining acceptability based on variation of these rates. The results of calibration checks performed at the beginning and end of each typical sample string are required to be within ±10% of the accuracy-based value for standards in order to consider the instrument used to be within calibration. The results of spike blank analysis are required be within ±20% of the correct value in order for the method to be considered in a state of control. All samples must be quantified within the calibration range. Quantification based on extrapolation is not acceptable.

Method Detection Limits (MDLs) are calculated and reported annually on a matrix and analyte basis. Since 1989, the method used for calculating MDLs is that used by EPA and is described in detail in the 7/1/88 edition of the Federal Register (Definition and Procedure for the Determination of the Methods Detection Limits - Revision 1.11). If the EPA method is not used or is modified, the procedure used for MDL calculation is described in detail. Separate MDLs are calculated for mussels and oysters.

Acceptable limits of precision for organic control materials are ±30% on average for all analytes, and ±35% for individual analytes. These limits apply to those materials where the concentrations of the compounds of interest are at least 10 times greater than the MDLs. The application of these guidelines in determining the acceptability of the results of the analysis of a sample is a matter of professional judgement on the part of the analyst, especially in cases where the analyte level(s) are near the limit of detection.

Reference Materials

To identify suitable reference materials for use by the NS&T Program and following the recommendation of the Intergovernmental Oceanographic Commission/United Nations Environment Programme/International Atomic Energy Agency (IAEA) Group of Experts of Standards and Reference Materials (GESREM), in 1986 NOAA began a compilation of standard and reference materials for use in marine science (Cantillo and Calder, 1990; Cantillo, 1993). In response to the needs of the NS&T Program, NOAA contributed funds to the production of eight NIST Standard Reference Materials (SRMs) and seven internal standard solutions (Table 2). The SRMs are based on natural matrices and are prepared at two concentration levels. The calibration solutions are for each of the three chemical classes of analytes quantified by the NS&T Program. The latter are used to facilitate the preparation of multipoint calibration curves. The internal standard solutions were prepared at the request of the NS&T contract laboratories and are currently available for purchase from NIST. These SRMs, CRMs, and control materials have been, and continue to be, used by NS&T contract laboratories to maintain analytical control.

Control Charts

The results of the routine analysis of RMs, other control materials, and blanks are reported annually to the NS&T Program office and are used to prepare control charts. Representative 1991 control charts for

Table 2. NIST SRMs and internal standard solutions partially funded by the NS&T Program.

SRM 1491	Aromatic Hydrocarbons in Hexane/Toluene
SRM 1492	Chlorinated Pesticides in Hexane
SRM 1493	Chlorinated Biphenyl Congeners in 2,2,4-Trimethylpentane
SRM 1941	Organics in Marine Sediment
SRM 1974	Organics in Mussel Tissue (*Mytilus edulis*)
SRM 2260	Aromatic Hydrocarbons in Toluene (Nominal Concentration 60 μg/mL)
SRM 2261	Chlorinated Pesticides in Hexane (Nominal Concentration 2 μg/mL)
SRM 2262	Chlorinated Biphenyl Congeners in 2,2,4-Trimethylpentane (Nominal Concentration 2 μg/mL)
AH	Naphthalene-d_8, acenaphthene-d_{10}, benzo[a]pyrene-d_{12}, perylene-d_{12}
PES	1,2,3-Trichlorobenzene, 4,4'-dibromooctafluorobiphenyl
TCMX	2,4,5,6-Tetrachloro-*m*-xylene
HMB	Hexamethylbenzene
COP Spike	Coprostan-3b-ol
COP I-STD	5a-Androstan-3b-ol
COP GC Cal.	Hexamethylbenzene, coprostan-3b-ol, 5a-androstan-3b-ol

the analysis of tissue show good accuracy and precision for phenanthrene and pyrene, and the PCBs 66, 105 and 187 (Figure 1 and 2). Some of the congeners quantified as part of the NS&T Program coelute when

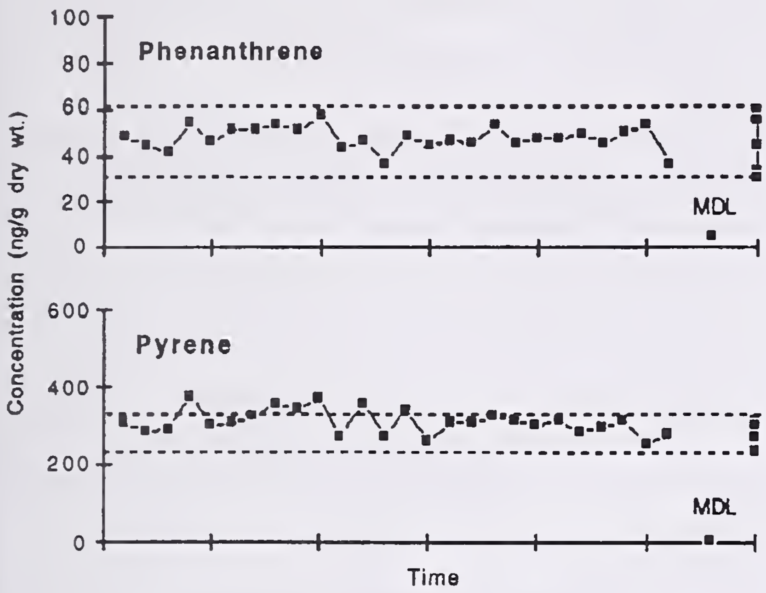

Figure 1. 1991 results of analysis of SRM 1974, Organics in Mussel Tissue, as control material for phenanthrene and pyrene by one of the NS&T cooperating laboratories [Notation to the right indicates the certified value, if available, the 95% uncertainty range, and ±35% of the uncertainty range. MDL is the minimum detectable level.] (ng/g dry wt.).

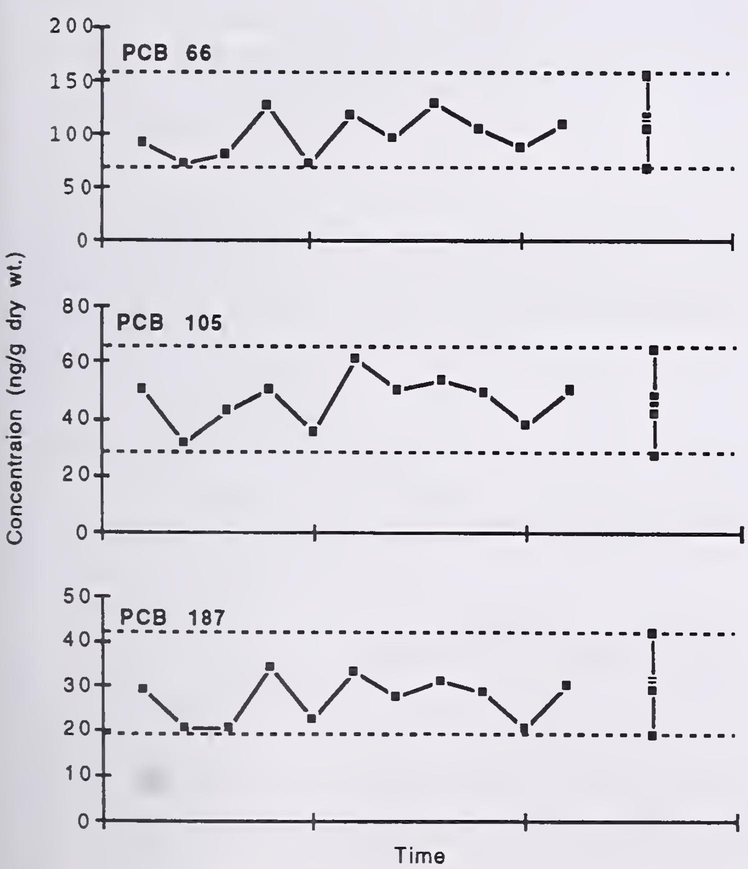

Figure 2. 1991 results of analysis of SRM 1974, Organics in Mussel Tissue, as control material for PCBs 66, 105 and 187 by one of the NS&T cooperating laboratories [Notation to the right indicates the certified value, if available, the 95% uncertainty range, and ±35% of the uncertainty range. MDL is the minimum detectable level.] (ng/g dry wt.).

using commonly available gas chromatography columns for analyte separation. A discussion of this topic can be found in Lauenstein and Cantillo (1993) and Schantz *et al.* (1993). Similar results for Ag, Al, As and Cd show good analytical control for Ag, As and Cd but problems with precision and accuracy for Al (Figure 3). These results are for two laboratories that have analyzed Mussel Watch Project samples since its inception in 1986.

Intercomparison Exercises

All NS&T laboratories are required to participate in yearly intercomparison exercises for tissue and sediment analyses. Results of the exercises prior to 1991 are described in Cantillo and Parris (1993) and Valette-Silver (1992), and those of 1991 through 1993 in Cantillo (1995). The materials used for the

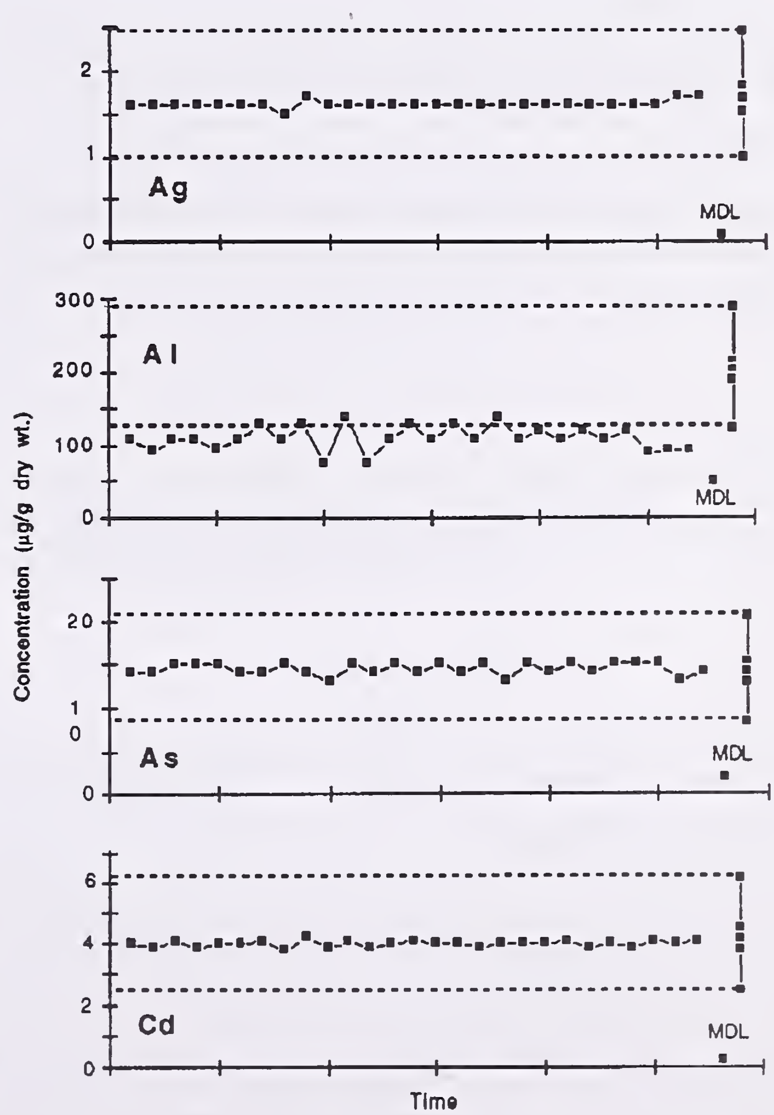

Figure 3. 1991 results of analysis of SRM 1566a, Oyster Tissue, as control material for Ag, Al, As and Cd by one of the NS&T cooperating laboratories [Notation to the right indicates the certified value, the 95% uncertainty range, and ±35% of the uncertainty range. MDL is the method detection limit.] (µg/g dry weight).

intercomparison exercises include samples with unknown contaminant concentrations, and SRMs and/or CRMs. The type and matrix of the exercise materials change yearly and have increased in complexity over time. The results of the intercomparison exercises are not intended to be a reflection of the absolute capability of a laboratory. Given time and budgetary constraints, the methodology used may not be the one resulting in the lowest detection limits or best precision, rather, it is the one that can be used to generate data of the quality specified by the NS&T Program. Typical results of the intercomparison exercises are discussed below.

Two sediment and two tissue materials were used for the 1993 intercomparison exercise for trace metals. NRC BCSS-1 and SRM 1566a were the known materials, and NRC prepared Sediment T, a freeze-dried Mississippi Delta sediment, and Tissue S, a freeze-dried mussel tissue homogenate collected by IAEA in the Mediterranean off the coast of France, as the unknowns. Typical results of intercalibration exercises for the NS&T cooperating laboratories are shown in Figure 4.

Results of analyses of SRMs and/or CRMs are not compiled and evaluated as part of the trace organic intercomparison exercises. Rather, unknown materials are prepared by NIST for each exercise. SRMs and CRMs are analyzed as part of of the analytical sample string in which the unknown materials are analyzed. These results are part of the control chart information described above. Some of the materials used for trace organic exercises, however, are cuts of the material used to prepare NIST SRMs or are candidate SRMs in the certification process and so are, in effect, unknowns.

As part of the 1993 trace organic exercise, a fish homogenate of carp collected in Saginaw Bay was prepared by NRC and provided to NIST. This material was analyzed for all NS&T analytes except polycyclic aromatic hydrocarbons, since these compounds are found in very low concentrations in fish tissue. Typical PCB results are shown in Figure 5. Most of the PCB results fall within the range defined as ±35% of the consensus value plus or minus one standard deviation.

Performance Improvement

In has been shown that the performance of laboratories improves with time, as the result of experience gained through participation in intercomparison exercises (Cantillo, 1995; Willie and Berman 1995a, 1995b, 1995c, and 1995d). This improvement can only be demonstrated through the

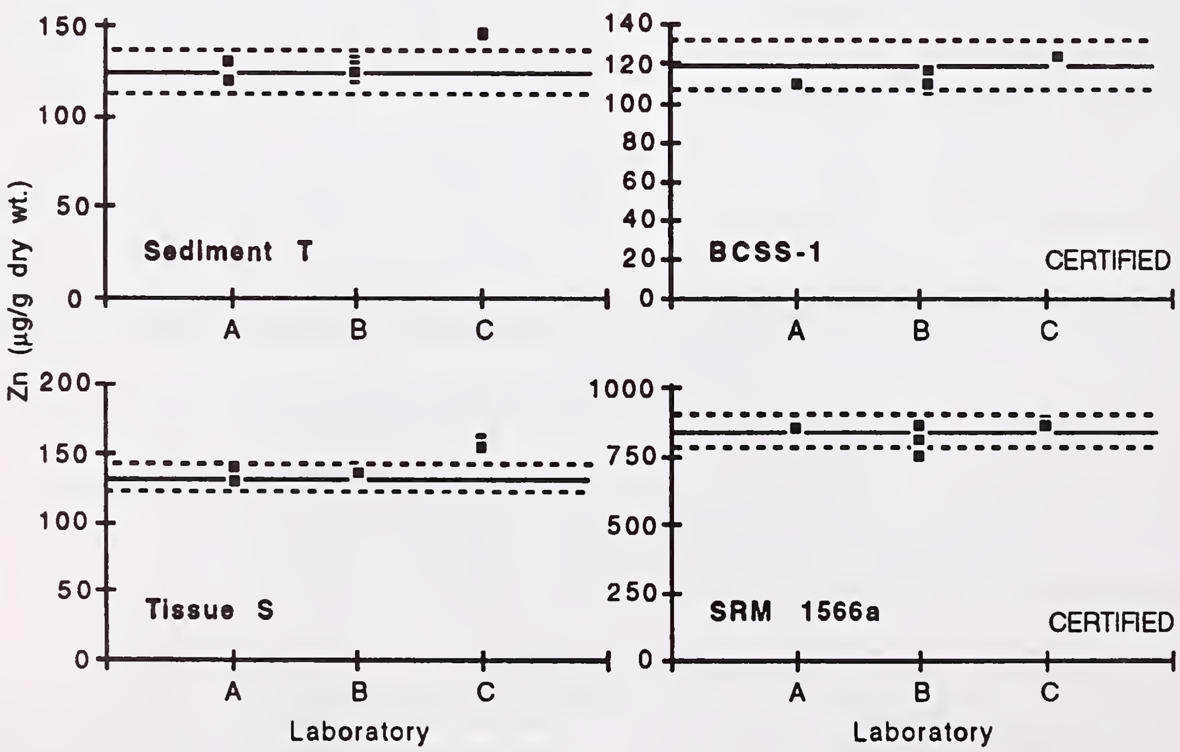

Figure 4. 1993 Zn intercomparison exercise results of five replicates for Sediment T, BCSS-1, Tissue S and SRM 1566a (Solid line is the certified value, if available, or the accepted value determined by NRC using exercise results. Dashed line is ± uncertainty at 95%.) (µg/g dry wt.).

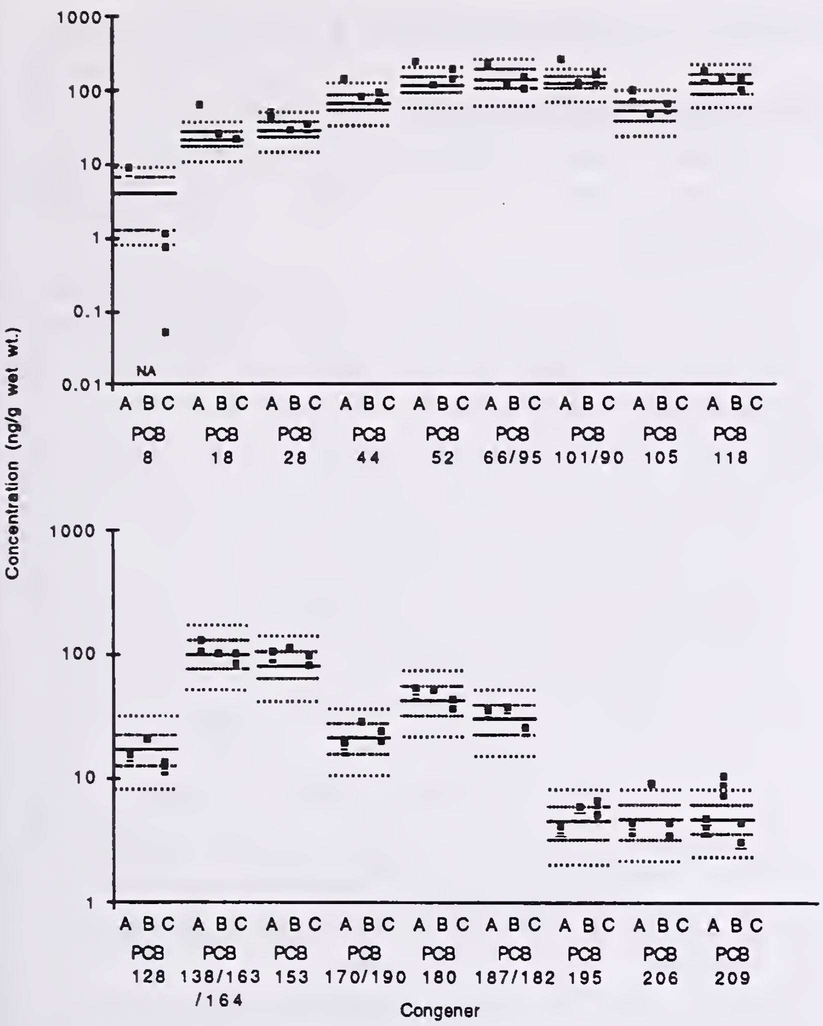

Figure 5. 1991 through 1993 Cr, Zn, Se and Sn intercomparison exercise results of five replicates of BCSS-1 reported by a laboratory participating in the exercises for the first time in 1991 (Solid line is the certified value. Dashed lines are ± uncertainty.) (µg/g dry wt.).

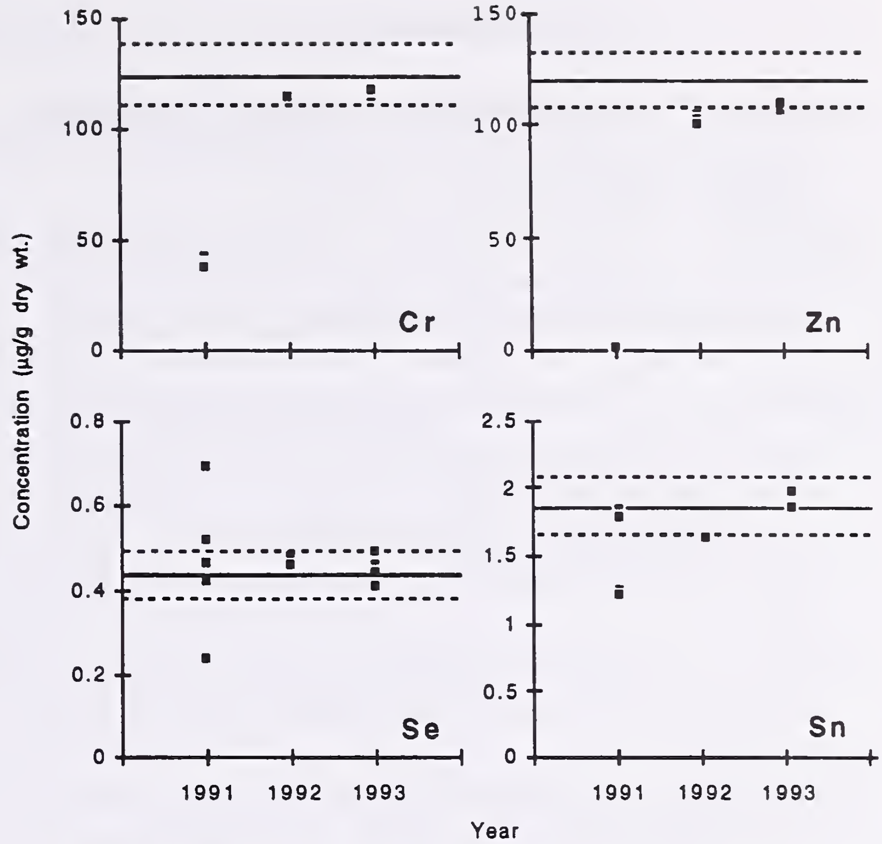

Figure 6. 1991 through 1993 Cr, Zn, Se and Sn intercomparison exercise results of five replicates of BCSS-1 reported by a laboratory participating in the exercises for the first time in 1991 (Solid line is the certified value. Dashed lines are ± uncertainty.) (µg/g dry wt.).

continued analysis of a material, such as a CRM, SRM or a control material with known analyte concentrations. The NOAA intercomparison exercises for trace metals for 1991 through 1993 used BCSS-1 as part of the exercise materials. Typical results reported by a laboratory joining the exercise program in 1991 are shown in Figure 6. The accuracy of the Cr, Zn and Se determinations improved with time, as did the precision of the Se analysis.

No CRMs or SRMs are analyzed specifically as part of the trace organic intercomparison exercises, so an evaluation similar to the one done for the trace metal exercises using changes in CRM and SRM results over time is not possible. A measure of improvement of laboratory performance can be made, however, by comparing the performance of a laboratory joining the exercises for the first time and that of a laboratory that has participated for several years. Laboratories newly joining the exercises usually have larger percent errors than the veteran laboratories. Within a year or two, however, the performance of the new laboratories typically improves and equals those of the veteran laboratories.

CONCLUSION

Quality assurance is an essential part of environmental monitoring programs, especially those that are not constrained by specified analytical procedures. The performance based QA project described in this paper allows for the introduction of new instrumentation and analytical techniques that may result in improved data quality or savings in time and resources. Analytical precision and accuracy of new laboratories joining an existing monitoring program can be quantified and improved, and the performance of veteran laboratories can be monitored and corrected if necessary. CRMs and SRMs provide the benchmark necessary to document laboratory performance.

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Monitoring for Ecological Assessment of Terrestrial and Aquatic Ecosystems

Dr. Hague H. Vaughan[1]

Abstract.–Conducting fundamental research in support of government policy, the Ecosystem Conservation Directorate's research institutions (the National Water Research Institute and the National Hydrology Research Institute) are constantly confronting the constraints imposed on analysis and assessment by the need for, and nature of, ecosystem approaches. Brief examples from current research will be described illustrating the doubtless familiar difficulties resulting from:

a) the need to define a Unit of Study which effectively includes socio-economics and the increasing inability to assume stable boundary conditions;
b) unexpected consequences, nonlinear responses, thresholds and ecosystem effects;
c) interacting effects; and
d) the need to develop publicly meaningful assessments.

As a result, our research is increasingly organized according to the exact nature of needed information. In pursuit of effective ecosystem management, appropriate assessment and reporting objectives may include: the identification of opportunities to minimize or mitigate effects; the prediction of resource use conflicts; the articulation of required public choices; the identification of short and long-term costs and benefits; and the development of meaningful measures of progress towards a publicly defined state of "sustainability". These are not traditional measures of success for research scientists or institutions. Such revised objectives are also useful in defining the roles that effective Ecosystem Monitoring will be expected to efficiently address.

Science in Support of Solutions: Ecosystem Conservation Directorate Approaches to the Analysis, Assessment, and Reporting of Ecosystem Status

INTRODUCTION

To a far greater extent than in the United States, much of the research into the management of natural resources in Canada takes place in federal and provincial government institutions as opposed to universities and the private sector. The Ecosystem Conservation Directorate's National Water Research Institute (NWRI) located in Burlington, Ontario and National Hydrology Research Institute (NHRI) in Saskatoon, Saskatchewan are two of the larger such institutions. The Ecosystem Conservation Directorate is one of the major divisions of the federal Department of Environment, its mandate differentiated from that of other internal organizational units which address environmental protection, the atmospheric environment, wildlife and state of environment reporting as well as from that of other federal departments which deal with fisheries and oceans, agriculture, forestry, energy and mines, national parks indian affairs and human health. Then of course there is a broad spec-

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trum of provincial and other agencies. The analysis and assessment of ecosystems increasingly demands that many of these organizational "fences" be crossed and this is fairly routine at the project level.

THE PROBLEM

NWRI and NHRI's purpose is to conduct fundamental research in support of government policy and actions. Many of their resulting objectives are shared with environmental monitoring and assessment networks (EMANs) despite that fact that research tends to be case specific and EMANs site(s) specific. Such common objectives include:

- defining the ecosystem effects of new and known stressors;
- assessing the adequacy of existing policy including identifying needs for revisions or new policy initiatives;
- developing science in support of control programs and the establishment of government priorities;
- detection and preliminary assessment of emerging problems;
- establishment of ecosystem status, trends, critical thresholds and management objectives;
- understanding cause and effect, particularly where there are multiple stressors, and ecological processes.

The list could go on but the point to be made is that the basic objectives of research institutions such as ours and those of EMANs are very similar and reflect broader societal needs related to the effective management of ecosystems. Just as those needs have evolved, NWRI and NHRI research has increasingly focused on ecosystems rather than individual variables, processes or populations. In doing so, we come up against aspects and properties of ecosystems which strain familiar approaches to analysis and assessment as well as our ability to confidently fulfill the above objectives based on the sufficiency of our knowledge and understanding. This uncertainty is compounded by the realization that possibly the most important issue we are attempting to address is the interface between science and decision-making. (e.g., Mitchell and Shrubsole. 1994)

1) The Unit of Study

In conducting science which tests or supports policy, it soon becomes clear that needed policy must incorporate considerations of environment, sociology and economics in some equitable manner: therefore so must supporting science. We increasingly find ourselves conducting research which is designed to address specific issues or needs within a larger ecosystem management strategy which we help to develop, in which we participate and which we advocate. This can become very convoluted. Examples include the Great Lakes "Lakewide Management Plans" (LaMPs) and "Remedial Action Plans" (RAPS), as well as Regional basin studies such as the Fraser River Action Plan or the Northern River Basins Study (NRBS) in northern Alberta. (Bertram and Reynoldson, 1992. Environment Canada, 1995. FRAP, 1995a and 1995b. MacKenzie, 1993)

In, for example, the Lake Erie LaMP process, our research is aimed at the understanding of unique lake processes and the prediction of the consequences of various management choices. The latter involves the identification of environmentally unsustainable conditions and actions. In order to ensure the effectiveness of our research, we have to assume, advocate and participate in a management process in which the need for sustainable choices can be presented, the alternatives soundly articulated and scientific activities based on the resulting decisions can be implemented. Suddenly, we find ourselves involved in ecosystem decision-making processes and this has the effect of altering the familiar pattern of analysis, assessment and reporting. We now have to consider the precise nature of, and need for, generated information and recognize that our information runs the risk of being misleading or inadequately appreciated if we fail to give sufficient weight to social and economic factors. The details of appropriate and effective reporting soon begin to drive research.

In the case of both the Hamilton Harbour RAP and the NRBS, research is being implemented in response to a formal process whereby desirable ecosystem endpoints are publicly defined, scientifically "translated" into required ecosystem attributes or values and presented for public debate where conflicts or choices arise. This process results in a set of activities required to bring the endpoints about, some of which

are specific monitoring, assessment or research activities. Priorities are publicly established, funding and cooperation are sought and needed actions are undertaken. That at least is the theory. (Gardiner et al., 1994. Hamilton Harbour RAP, 1992. NRBS, 1994)

Equal difficulties are presented by an inability to assume stable boundary conditions for the ecosystem under study. While recognizing that anything we call an ecosystem is a nested sub-system of a larger ecosystem, we formerly could at least assume that if we were dealing with, for example, a basin, climate variables could be treated as constant or varying in a predictable manner. With the regrettable emergence of world-wide environmental issues, we must increasingly include UV-B, climatic variables and toxic deposition as real sources of ecosystem stress. Our ability to isolate cause and effect or to predict consequences is sharply reduced.

2) Unexpected Consequences, Nonlinear Responses, Thresholds and Ecosystem Effects

These are of course the "stuff" of ecosystem studies: emergent properties which sap the confidence of researchers and confound their attempts to apply and interpret traditional experimental or descriptive approaches. Once again the analysis, assessment and reporting model may not be the most effective one for the development of solutions to problems in ecosystem management.

NWRI and NHRI research abounds (as does research elsewhere) in examples of activities which incorporate considerations of these issues. Research into sediment flocculation, estrogenic substances, ice-jamming, the responses of northern ecosystems to altered hydrology, ecotoxicology, etc.: all contain extensive examples. Less often seen are true ecosystem effects. NHRI's Max Bothwell has been conducting experiments on the response of attached algae to UV-B in shallow water flumes. As expected, he observes that primary production is lower in flumes not shielded from UV radiation. Over longer periods he has been surprised to observe the apparent reversal of this situation: attached algal biomass is plainly lower in the protected flumes after three weeks. The reason is that UV radiation does indeed suppress primary productivity in the unshielded flume but it suppresses the grazing community even more. The net result is a higher standing crop. The insidious aspect of this is the appearance of health in the fully exposed flumes due to a "bottleneck" in the upward transfer of energy. (Bothwell, 1974)

Dr Bothwell's work has been chosen as one of the top science stories of 1974 by Discover Magazine (Discover, 1995) and is acknowledged to be one of the few instances of a demonstrated "ecosystem effect". Every ecologist knows that such effects ripple through the food webs of ecosystems yet this may be the first demonstrated instance of such a phenomenon!

3) Interacting Effects

It can be safely said that no ecosystem exhibits a response to a single stressor unless that stressor is so overwhelming in its impact as to seriously degrade or destroy the system under study. I can't prove this but it is intuitively sensible. In the normal course of events an ecosystem is in the process of catching up to an entire spectrum of altering conditions. Therefore, any moderate change in an ecosystem is in all probability a reflection of a range of interacting stressors. The result is that as we attempt to develop predictive capabilities for ecosystems based on observation or experimentation, presumptions regarding cause and effect are likely to be incorrect in any but the most extreme circumstances.

An example of this is NWRI and NHRI's evolving focus on the study of brown-water lakes and associated wetlands as sites where the effects of climate change and UV-B interact. Climate variables control the generation of organic acids from surrounding wetlands. These acids attenuate the penetration of UV-B in open water and therefore define the areas where effects will be felt. At the same time, UV-B breaks down those acids generating peroxide and other strong oxidizers as well as releasing associated metals. The oxidizers in turn affect a many aspects of aquatic chemistry and related system processes. Climate variables also directly affect the distribution and diversity of emergent vegetation and UV-B directly affects the health and survival of organisms. Will we ever sort all this out? Possibly, but our present objectives are more modest:

- to study effects and response thresholds in a sensitive ecosystem;
- to use these to differentiate between a degree of climate variability which is

- relatively normal and one which represents an induced alteration;
- to identify opportunities to minimize or mitigate the impacts of climate alteration and increasing UV-B.

4) The Need to Develop Publicly Meaningful Assessments

The many difficulties presented by pursuit of an understanding of ecosystems force upon researchers and research managers a rather difficult choice: whether to develop deeper understanding as the primary objective or whether to develop sound information in a form which can be used in decision-making. The motivations, priorities, measures of success and rewards of scientists being rather different than those of decision-makers, the two are rarely the same. (Cullen, 1990)

THE RESPONSE

Our research programs and priorities are increasingly organized according to the exact nature of needed information. In pursuit of effective ecosystem management, our institutional assessment and reporting objectives, in addition to those above, now include:

- the identification of opportunities to minimize or mitigate effects;
- the prediction, and development of recommendations for resolution, of resource use conflicts;
- the articulation of required public choices;
- the identification of environmental, social and economic short- and long-term costs and benefits; and
- the development of meaningful measures of progress towards a publicly defined state of "sustainability".

This increased emphasis on producing useful information in the form in which it is most likely to foster and contribute to inclusive ecosystem approaches to resource management has tended to alter analysis, assessment and reporting procedures by placing consideration of the reporting aspects up front.

Further, these are not the traditional measures of success for scientists. Their status, promotion and funding are usually directly related to peer reviewed papers with other considerations being a distant second. We seek out and hire the best research scientists we can find. While some may be excellent public communicators, this is an unexpected bonus. For the most part, we address the above additional priorities through the allocation of personnel and resources to the synthesis and communication of science.

By communication, I mean far more than annual reports, newsletters, popular articles and public speeches. I mean a great many functions related to the nature of resource management, decision making and the role of research in society including:

- synthesis and integration across disciplines
- development of resource management options and choices
- advocacy, coordination and leadership within resource management processes
- technology transfer to operational programs, other agencies and the private sector;
- effective delivery to policy and decision makers of issue assessments, early warning, advice and recommendations;
- exploration and development of opportunities for partnerships, cooperation, cost-sharing, contracts and marketing

THE OPPORTUNITY

While ecosystem research and EMANs have many differing goals and objectives, they have many more in common. These are related to the need for science, scientists and scientific organizations to deliver effective information which will provide solutions and encourage an ecosystem approach to the management of natural resources. In this respect ecosystem research and EMANs can be viewed as parallel and complimentary.

One response of NWRI and NHRI to the complexities of ecosystems and the priority which must be given to the interface between science and decision-making has been an increased emphasis on the delivery of effective products and services which supplement the generation of knowledge. Similarly, the design of EMANs should give extensive consid-

eration to the exact form and nature of what it is they are to produce from ecosystem monitoring information and, given the nature of existing resource management and decision making, what lack(s) they can uniquely or most efficiently address.

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The Mid-Atlantic Integrated Assessment: Focus on Process

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Abstract.--The Mid-Atlantic Integrated Assessment (MAIA) was initially proposed as a partnership between the U.S. Environmental Protection Agency (EPA)'s Office of Research and Development and EPA Region III to develop and respond to the best available information on the condition of various resources and to adapt Regional management over time, based on careful monitoring of environmental indicators and related new information. The MAIA study area extends from southern New York into northeastern North Carolina and includes EPA Region III (i.e., PA, WV, MD, DE, and VA), and encompasses the area from the mid-Appalachian highlands to the estuaries, and thus includes a heterogenous system of agricultural lands, forested lands, wetlands, lakes, streams, rivers, coastal areas and estuaries. When asked to articulate their primary management questions, Region III administrators focused on the following: (1) what are the environmental problems within the Region? (2) are the problems getting better or worse? (3) what factors are causing the problems? and (4) what can regional administrators do about the problems? Region III senior managers felt that trying to state their questions more specifically might perpetuate common biases regarding the dominant environmental problems within the region rather than fostering an objective assessment.

INTRODUCTION

The Mid-Atlantic Integrated Assessment (MAIA) was originally proposed as a partnership between the U.S. Environmental Protection Agency (EPA)'s Office of Research and Development (ORD) and EPA Region III to develop and respond to the best available information on the condition of various resources and to adapt Regional management over time, based on careful monitoring of environmental indicators and related new information. Current management limitations include: minimal data on environmental indicators, and data specific to local scales, single media, or single resources. The challenge to the partnership between Region III and ORD has been to infuse management discussions and decisions with comprehensive environmental data, of known quality and certainty, that is useful to:

- multiple scale coverage such as watersheds, ecoregions, and ecosystems
- "place-based" management
- regional scale issues
- crossing environmental media
- integration across environmental resource areas.

The MAIA study area extends from southern New York into northeastern North Carolina and includes EPA Region III (i.e., PA, WV, MD, DE, and VA); the Susquehana and Allegheny river basins,

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which extend into New York; the Delaware River basin, which extends into New Jersey; and the Chowan-Roanoke and Neuse-Pamlico basins, which extend into North Carolina (Figure 1). The MAIA study area encompasses the area from the mid-Appalachian highlands to the estuaries, and thus includes a heterogenous system of agricultural lands, forested lands, wetlands, lakes, streams, rivers, coastal areas and estuaries (Waddell and Holland, 1994).

When asked to articulate their primary management questions, Region III administrators focused on the following:

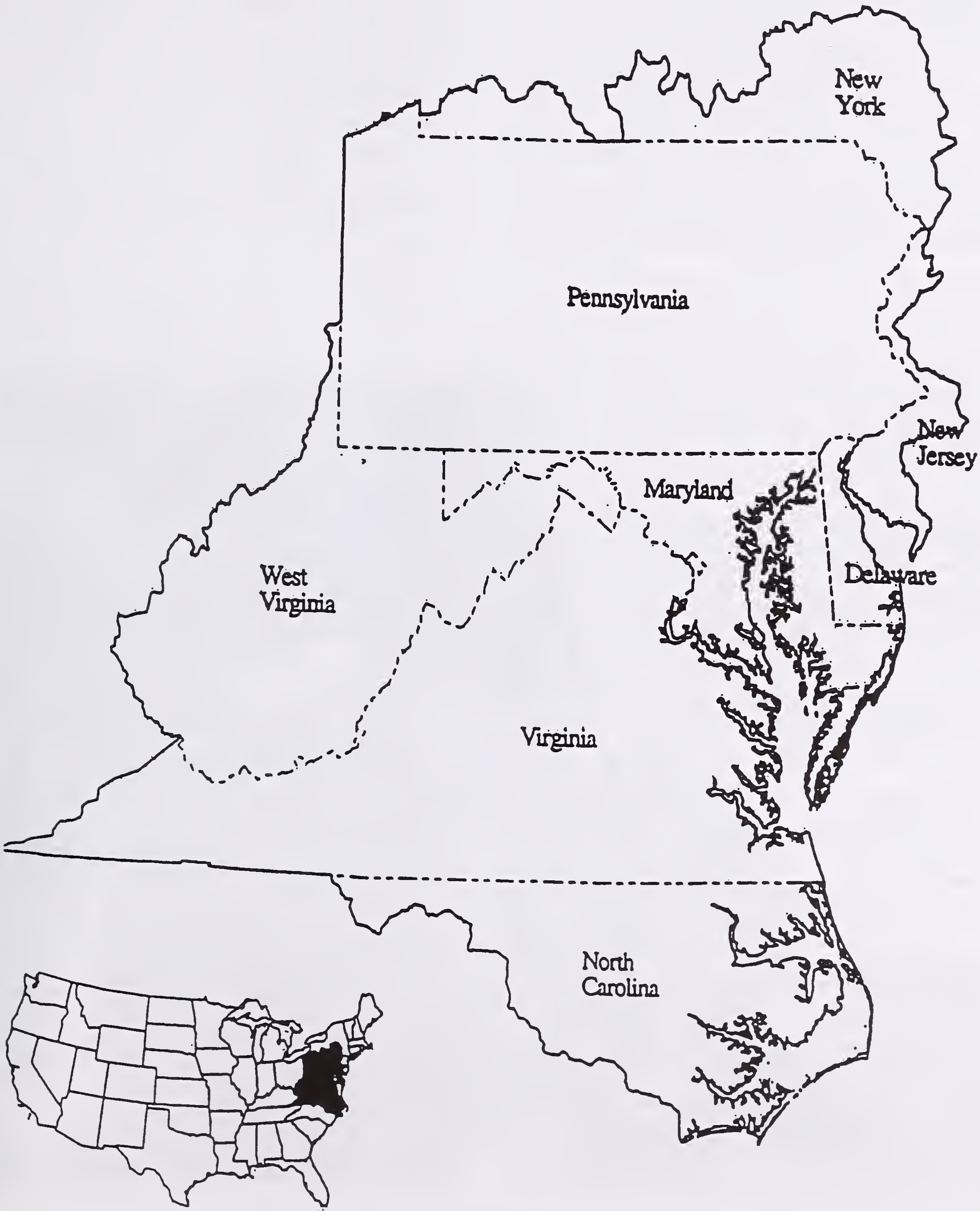

Figure 1. Region of study for the Mid-Atlantic Integrated Assessment.

- What are the environmental problems within the Region?
- Are the problems getting better or worse?
- What factors are causing the problems?
- What can regional administrators do about the problems?

The Region III senior managers indicated that they deliberately formulated very general questions and repeatedly declined to be more specific because they are looking for an objective appraisal of ecological conditions throughout the region. They feel that previous monitoring and assessment within the region frequently has been biased toward particular hot spots or problems of special interest to particular groups; consequently, previous assessments may not provide a balanced perspective for prioritizing management efforts. The managers felt that trying to state their questions more specifically might perpetuate common biases regarding the dominant environmental problems within the region rather than fostering an objective assessment.

A desire to find consistent region-wide performance indicators of water quality management programs led Region III personnel to seek advice from the Environmental Monitoring and Assessment Program (EMAP). Region III managers were concerned that different counties within the same watershed were reporting water quality values which varied by county boundaries (Figure 2). The attraction of EMAP was that it had developed a scientifically rigorous monitoring design (Overton et al. 1990) within which appropriate indicators can be sampled to provide information required to address various policy questions.

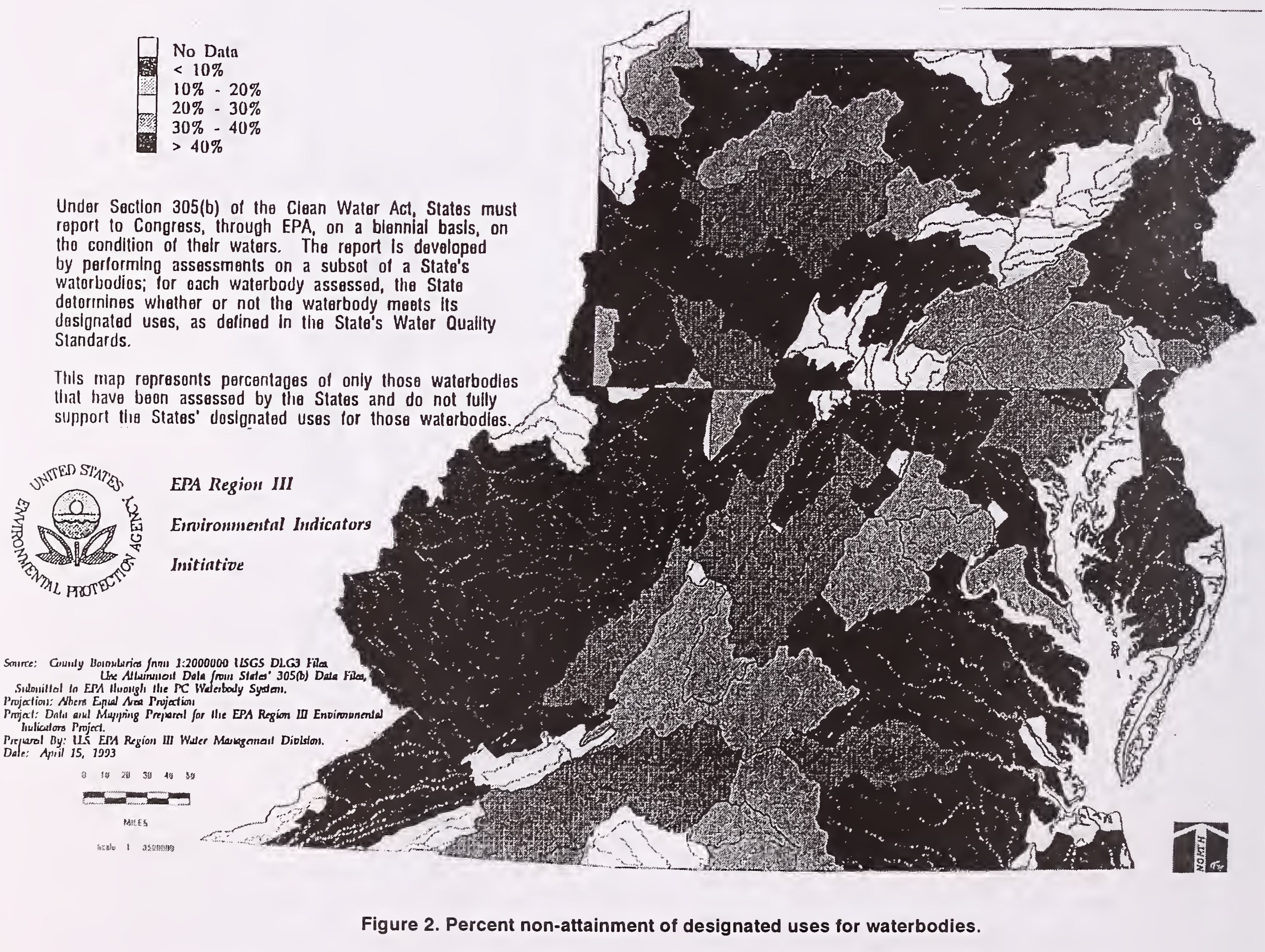

Figure 2. Percent non-attainment of designated uses for waterbodies.

EMAP developed as a multi-agency effort led by EPA to assess the condition of the USA's ecological resources (Messer et al. 1991). A primary goal of EMAP was to identify the extent and magnitude of environmental problems on regional and national scales and to provide information that policy makers, scientists, and the public need to evaluate the success of environmental policies and programs (Thornton et al. 1993). Region III senior managers noted that EMAP activities had improved on traditional compliance monitoring programs in the following ways:

- EMAP focuses on assessing ecological condition by measuring biological indicators. Biological indicators provide integrated measures of response to natural and human-induced stress that cannot be obtained from traditional chemical and physical indicators of environmental stresses such as pollutants and habitat modification. The program maintains a core set of indicators that are implemented nationally with uniform methodology and quality control (Barber 1994).
- EMAP uses a statistically rigorous sampling design. By measuring indicators within a network of probability samples rather than from sites selected using subjective criteria, EMAP produces unbiased estimates of the status of and changes in indicators of ecological condition with known confidence.
- EMAP takes an ecosystem-oriented approach to monitoring by sampling several ecological resources [e.g., agricultural lands, forests, estuaries, and surface waters, including lakes and streams] all of which are important components of the landscape of Region III.

PURPOSE OF MAIA

MAIA has been viewed by both Region III and ORD personnel as a process which injects the best science into assessment activities in the mid-Atlantic region. MAIA's research activities are directed toward the fundamental scientific issues posed by regional, integrated assessment. Region III managers use MAIA's assessment results to guide environmental management. MAIA, therefore, is both a process-driven (research) and product-driven (assessment) activity with the following three-pronged objective:

To conduct ecological research in the mid-Atlantic region that addresses

- condition, spatial characteristics, and associations of single ecological resources at both regional and sub-regional scales;
- associations between the condition of single ecological resources with landscape attributes and stressor data;
- relationships across multiple ecological resources and at different spatial scales that affect overall ecosystem condition.

Conducting such a wide range of research within one region enables researchers to develop the analytical methods for producing integrated ecological assessments on successively larger scales using more and more indicators, while producing interim products of immediate interest to resource managers in the MAIA study area. MAIA offers an opportunity to address a variety of scientific questions related to the conduct of an integrated regional assessment because the mid-Atlantic region possesses both the most extensive data sets yet developed for describing the condition of multiple resources, and the institutional interest from Region III needed to pursue an integrated assessment.

Region III has identified numerous management issues that demand attention and improved information. Table 1 identifies Region III's primary management concerns. These issues relate to regulatory and management responsibilities of certain EPA programs and their authorizing legislation. Having identified these management concerns, Region III and EMAP can formulate assessment questions for MAIA. The list of management concerns suggests the need to focus on using appropriate biological indicators in water monitoring strategies, characterizing the relationship between land use and habitat elements, identifying threats to biological diversity, and evaluating ecological risks. MAIA's condition-driven approach is ideally suited to meetings these needs.

A major goal of MAIA is to provide a specific geographic context for identifying the best way to assess large-scale ecosystems. This involves developing a better understanding of how relationships among categories of ecological resources are impor-

Table 1. Management issues concerning ecological resources in Region III.

Management Issues	Environmental Authority
Use of biological indicators instead of chemical indicators as performance measures in surface water quality management	Clean Water Act
Threats to biodiversity and unique species	Endangered Species Act Toxic Substances Control Act Clean Air Act Clean Water Act
Effect of land use changes on extent and quality of habitat	Endangered Species Act Clean Water Act
Effect of acid deposition on ecological resources	Clean Air Act
Relationship between land use configuration (e.g., nonpoint source activities) and environmental quality	Clean Water Act
Ability to describe the state of the environment	General
Comparative risk of ecological resource problems in the mid-Atlantic region for strategic planning	General

tant in characterizing overall ecosystem health and how assessments can contribute to explaining linkages between condition and stressors. Questions about ecosystem health will be examined using ancillary stressor data and ecological risk assessment methods. Developing accurate and relevant measures of ecosystem health is important to ensure that

- subtle changes in overall resource condition are identified;
- nominal condition of one ecological resource is not masking poorer condition of an associated resource;
- landscape attributes related to resource condition are characterized sufficiently at appropriate scales; and
- strategies designed to address problems or to protect resources are directed appropriately.

REASONS FOR SELECTING THE MID-ATLANTIC

The mid-Atlantic is uniquely suited to the objectives of a regional integrated assessment because of the following characteristics:

- **Diversity of ecosystems**. The mid-Atlantic encompasses several ecoregions from the coastal plains, through the mid-Appalachian Plateau, to the highlands in the western portion of the study area. The region contains many kinds of ecosystems, including forests, agro-ecosystems, streams, lakes, estuaries, and tidal and non-tidal wetlands. It includes several major drainage basins, and encompasses all of the Chesapeake watershed.
- **Availability of EMAP Data.** The mid-Atlantic has been a nursery ground for EMAP research, including pilot projects for the estuaries, streams, forests, landscape characterization, and landscape ecology groups. No other part of the country has a comparable amount of EMAP data. This concentration of data frees MAIA to focus its effort on analyzing data and conducting specialty studies, rather than collecting data from the base EMAP frame. The availability of data also fosters integration of data from different kinds of resources, which is an important purpose of the project.
- **Wealth of additional data.** One of MAIA's goals is to merge EMAP data with other available data to provide the most comprehensive characterization of the region possible. Because of its dense population and proximity to Washington, DC, the MAIA study region is one of the most data-rich areas of the country. These additional data will allow researchers to perform analyses that would not be possible with EMAP data alone and enable EMAP scientists to assess which of EMAP's components contribute most to regional assessment and how.
- **Strong institutional partnership.** EPA Region III is committed to participating fully in implementing MAIA and using MAIA results to guide environmental and

resource management in the region. Region III has assigned more than 20 people to work on the assessment, allowing EMAP to leverage resources. The Region's knowledge of and access to databases for parts of the study area and Regional familiarity with the state and local agencies that collect and use these data will be essential to the success of the project.

MAIA STUDY BOUNDARIES

The MAIA study boundaries were defined to balance ideal technical considerations with practical logistical and political considerations. The criteria for determining the geographic boundaries for the assessment included political, ecoregion, and watershed considerations. To ensure the greatest technical utility, the boundaries include entire large river basins; these boundaries allow researchers and managers to investigate problems at different watershed scales. To ensure that delegated authorities can use MAIA information to make decisions about management strategies and allocations of resources, the boundaries generally align with jurisdictional responsibilities (i.e., Region III and individual states).

Figure 1 shows the boundaries of the MAIA study area. As mentioned previously, the area extends from southern New York into northeastern North Carolina and includes EPA Region III (i.e., PA, WV, MD, DE, and VA); the Susquehanna and Allegheny river basins, which extend into New York; the Delaware River basin, which extends into New Jersey; and the Chowan-Roanoke and Neuse-Pamlico basins, which extend into North Carolina. The MAIA study area encompasses the area from the mid-Appalachian highlands to the estuaries (Waddell and Holland, 1994). Figure 3 shows the major drainage basins (i.e., USGS Water Resource Subregions) in the study area. These basins can be subdivided into watersheds, depending on the issue being addressed. Different assessment questions will require different regional maps. For example, evaluating atmospheric deposition problems may require assessing airsheds, and characterizing the condition of wide-ranging species may require assessing vegetation-based habitat regions. Ecoregion schemes developed by Bailey (1980), Omernik (1987), and others often provide the best means of defining the boundaries of similar ecological resources: Figure 4 shows the ecoregions of the mid-Atlantic according to Omernik (1995). Analyses of the land use and land cover in the 1990's (Figure 5) will provide critical baseline information for future comparisons.

OTHER EPA INITIATIVES WITHIN THE MID-ATLANTIC REGION

Because of its geographic scope, MAIA will encompass numerous other important Region III geographic initiatives. MAIA is designed to capitalize on the knowledge, goals, and objectives of these initiatives rather than to replace or duplicate them. The major initiatives within the region include the Mid-Atlantic Highlands Assessment (MAHA), the Chesapeake Bay Program, and National Estuary Programs in the Delaware River, Delaware Inland Bays, and Albemarle-Pamlico estuaries. Working with these groups will improve MAIA's overall assessment and enable EMAP scientists to investigate issues of assessment scale.

MAHA is a major geographic project to assess the condition of the ecological resources in the mountain region of Virginia, Maryland, West Virginia, and Pennsylvania. The project is designed to (1) assess the current ecological condition of the mid-Atlantic highlands and its component ecoregions and states, (2) locate sensitive areas that need remediation or preservation, (3) examine associations between degradation of resources and possible causal factors, and (4) prioritize needs for further research into possible causes and consequences of pollution in the mid-Atlantic highlands. MAHA covers six major ecoregions, four states, and six major watersheds; the study area totals 65% of Region III. MAHA relies heavily on EMAP data for freshwater streams, forests, estuaries, and landscape ecology. MAHA was implemented to aid strategic planning and support decision making in Region III and the four states.

Region III developed partnerships with other federal agencies to coordinate and collaborate on activities. The assessment focuses on evaluating the condition of ecosystems, estimating the extent of the most pristine and most degraded areas, and measuring rates of change in the condition of these resources. In May, 1995, "The Highlands Accord" was signed between the U.S. Department of the Interior, the U.S. Department of Agriculture, and the U.S.

EMAP Sampling Within Major Drainage Basins in the Mid – Atlantic Region

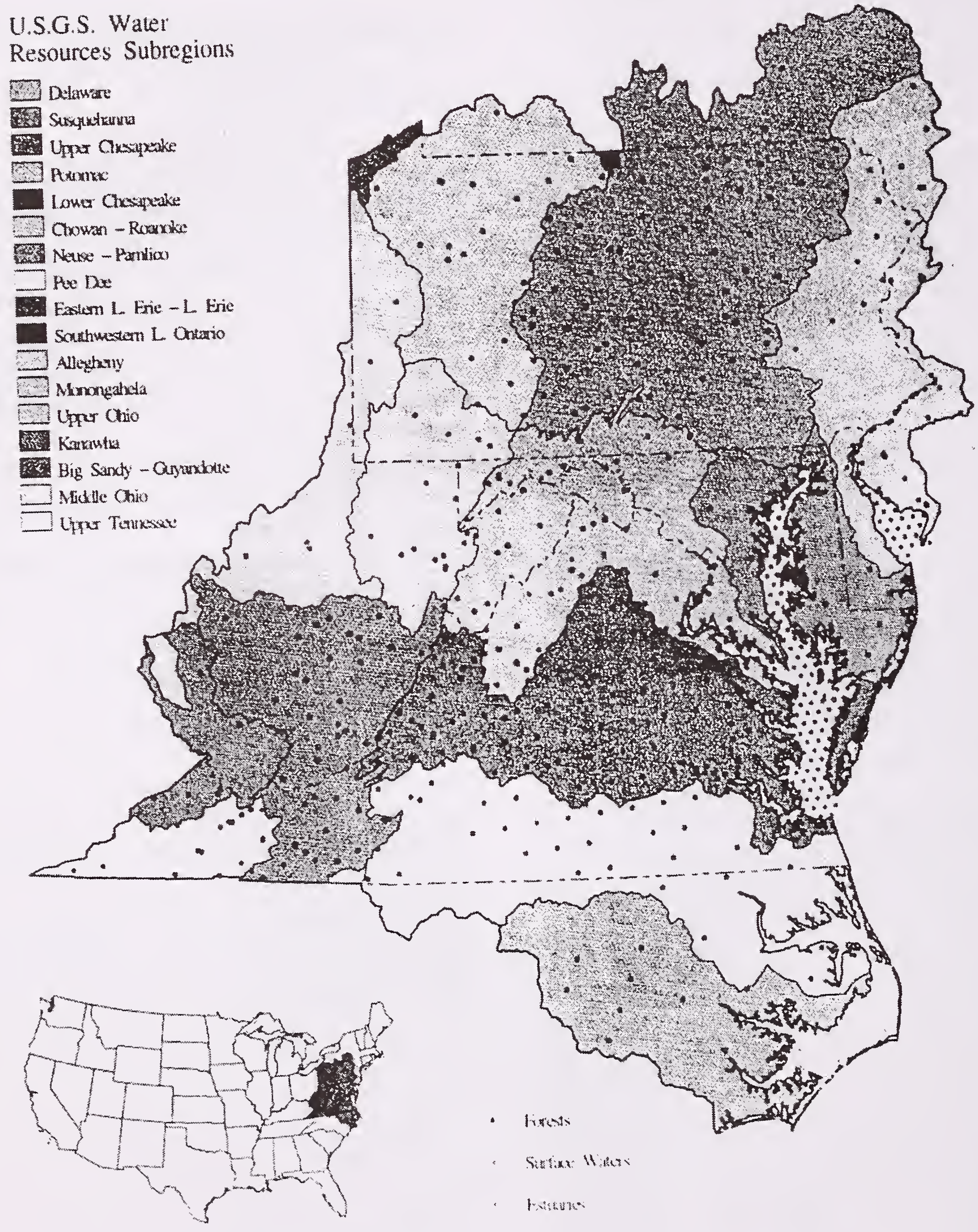

Figure 3. EMAP sampling within major drainage basins in the Mid-Atlantic region.

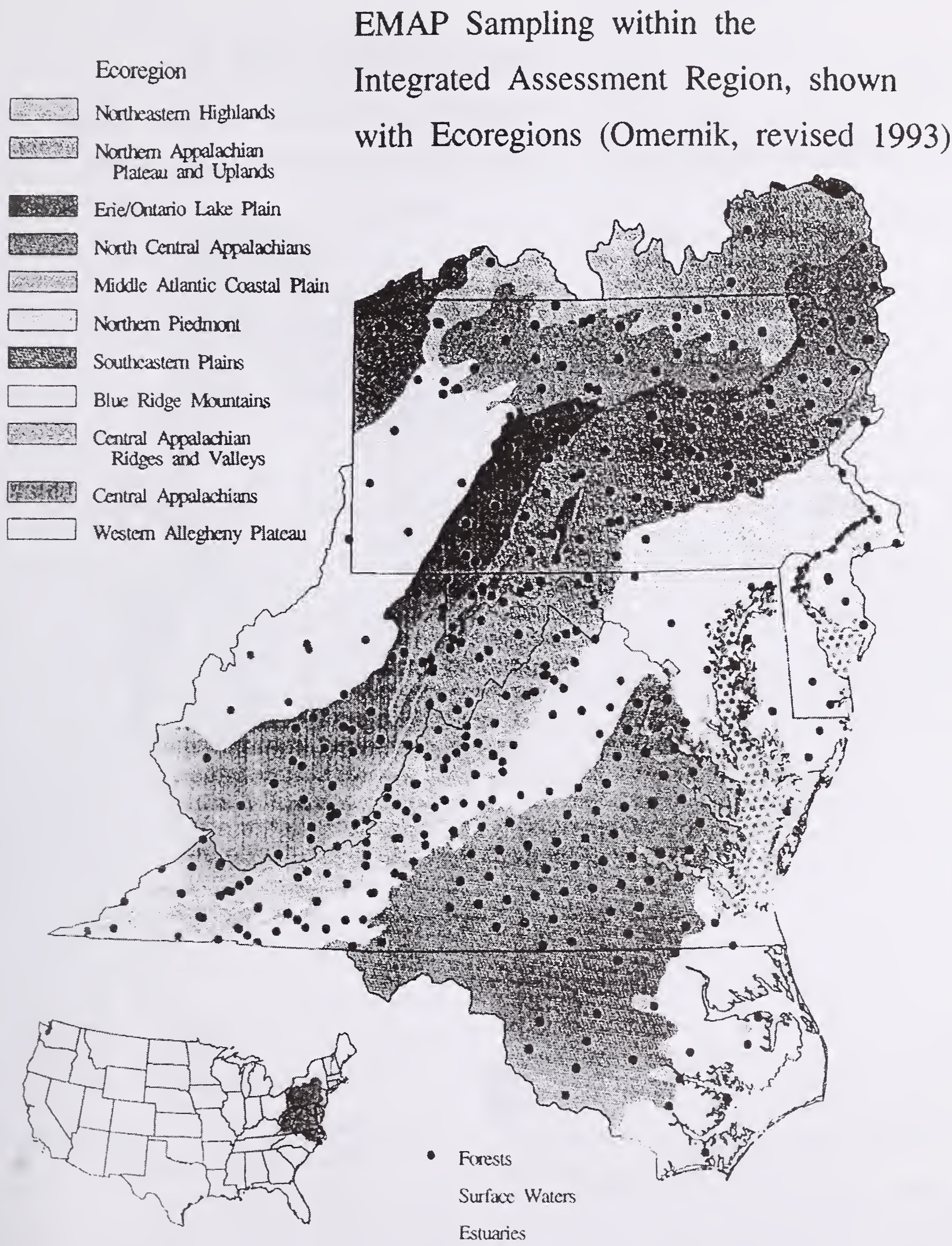

Figure 4. EMAP sampling within the integrated assessment region, shown with Ecoregions (Omernik, revised 1993).

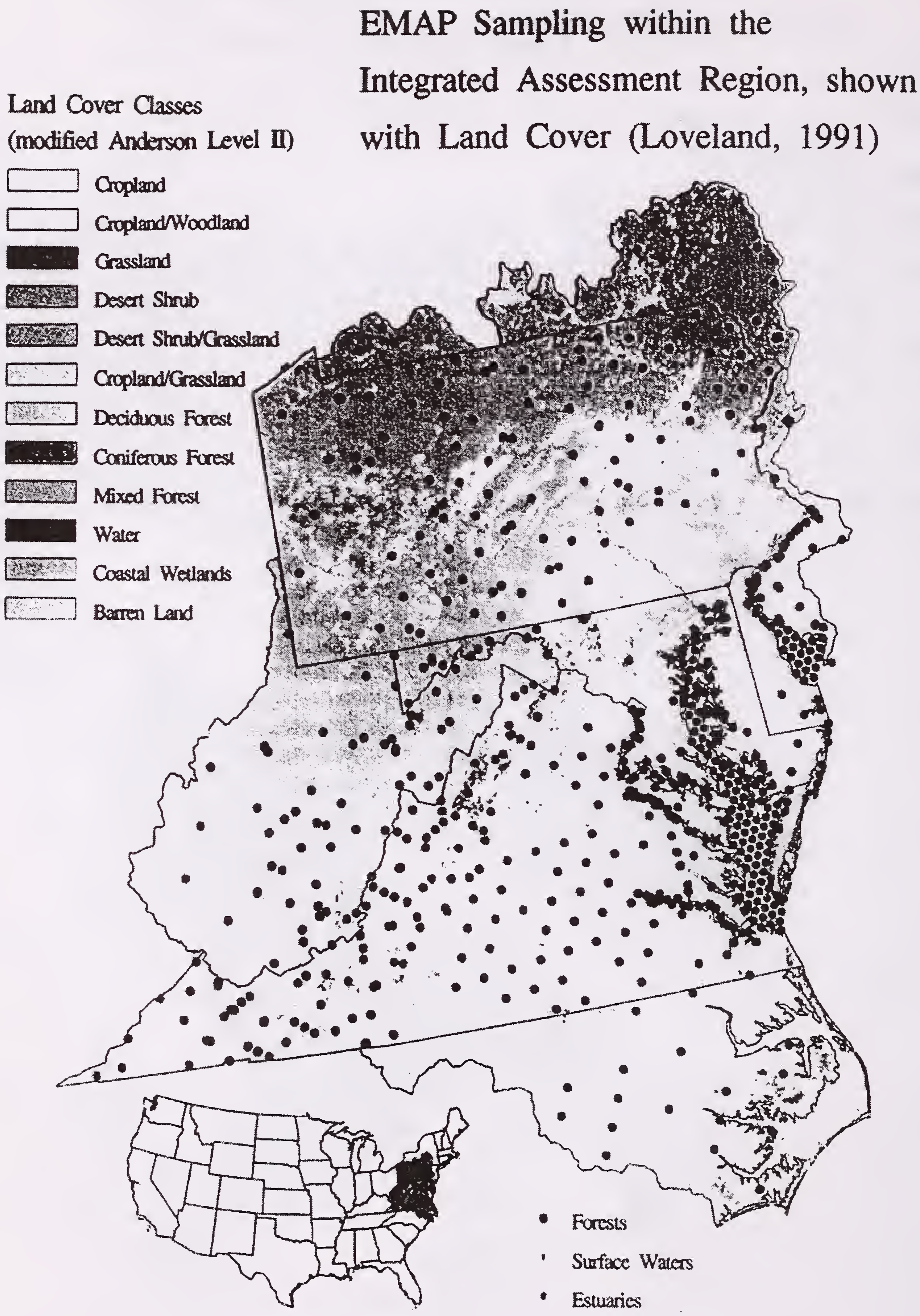

Figure 5. EMAP sampling within the integrated assessment region, shown with land cover (Loveland, 1991).

Environmental Protection Agency to establish a framework for regional cooperation and participation among various federal, state, and local parties in working toward a more holistic approach to the management of the Mid-Atlantic Highlands' natural resources (Memorandum of Understanding, 1995). Such a Memorandum facilitates sharing of information gathered through the efforts of each of the signatory parties, and will foster more collaborative management practices for the MAHA region.

The Chesapeake Bay Program continues to be a major geographic activity in Region III. To date the program has focused on reducing nutrient inputs to the bay by 40%. Nutrient inputs are linked to the bay's water quality and biological resources. Efforts to reduce nutrients include plans to reduce inputs to the bay's tributaries. Although phosphorus levels are lower than at the beginning of the effort, nitrogen levels have remained essentially steady because of increasing development and changing land use. Although progress has been made in restoring the living resources in the bay, problems remain. The effects of toxic inputs to the bay remain uncertain.

Region III and the states of Maryland and Delaware are assessing the condition of the coastal bays of Delaware and Maryland. Approximately 200 sites have been sampled for water quality, fish, benthic macroinvertebrates, and sediments using a stratified random design. These data will be used to address the following issues: (1) the extent and magnitude of ecological degradation in the study area, (2) the distribution of ecological degradation (i.e., uniform throughout the coastal bays or concentrated in specific areas), and (3) the potential associations between degradation and specific pollutants (e.g., nutrients, organic matter, toxicants). Comparing current and historical data will identify the amount of change that has taken place in the coastal bays during the last 20 years. The National Estuary Programs in the Delaware and Albemarle-Pamlico estuaries conducted similar studies as they developed their management plans.

OTHER FEDERAL INITIATIVES IN THE STUDY AREA

In addition to coordinating assessment activities with ongoing EPA initiatives in Region III, MAIA will capitalize, where possible, on geographic initiatives being undertaken by other federal agencies in the mid-Atlantic region, such as:

- Southern Appalachian Man and the Biosphere (SAMAB) Project
- National Biological Survey nationwide inventory, regional studies, and Gap Analysis Program for identifying hot spots of biodiversity
- USGS National Water Quality Assessment (NAWQA)
- U.S. Forest Service assessment initiatives
- NOAA Mid-Atlantic Regional Marine Research Program
- NSF Long-Term Ecological Research (LTER) site in the Virginia Coastal Plain

Many of the agencies responsible for these projects share MAIA's goal of understanding factors that degrade biological resources and using information about the condition of resources in making management decisions. For example, the U.S. Forest Service is interested in data about forest condition, and the National Biological Survey is interested in maximizing opportunities for collecting the full range of biological data. Some of these projects already have become involved in MAIA through participating in focus groups to identify the important management questions that the project will address. ORD scientists and Region III will attempt to obtain data produced by these projects, or better yet, involve them further in the MAIA assessment effort.

MAIA is a large undertaking with a five-year time frame; therefore, it will be implemented in stages (Figure 6). The approach begins with assessments of individual resources and progresses through stages of increasingly integrated assessments. Specifically, MAIA will produce three levels of assessments (1) single resource assessments, (2) landscape assessments, and (3) multiple resource assessments. The first assessments (0-2 years) will be based on existing data (from EMAP and elsewhere), while subsequent assessments (3-5 years) will augment existing data and methods with new monitoring data and research. Future assessments (beyond 5 years) will incorporate even more innovative methods and the results of longer-term research.

Specifically, MAIA will produce assessments at four levels of integration (Figure 7):

- Level one — Single resource assessments - determining the status and trends in the condition of individual ecological resources.

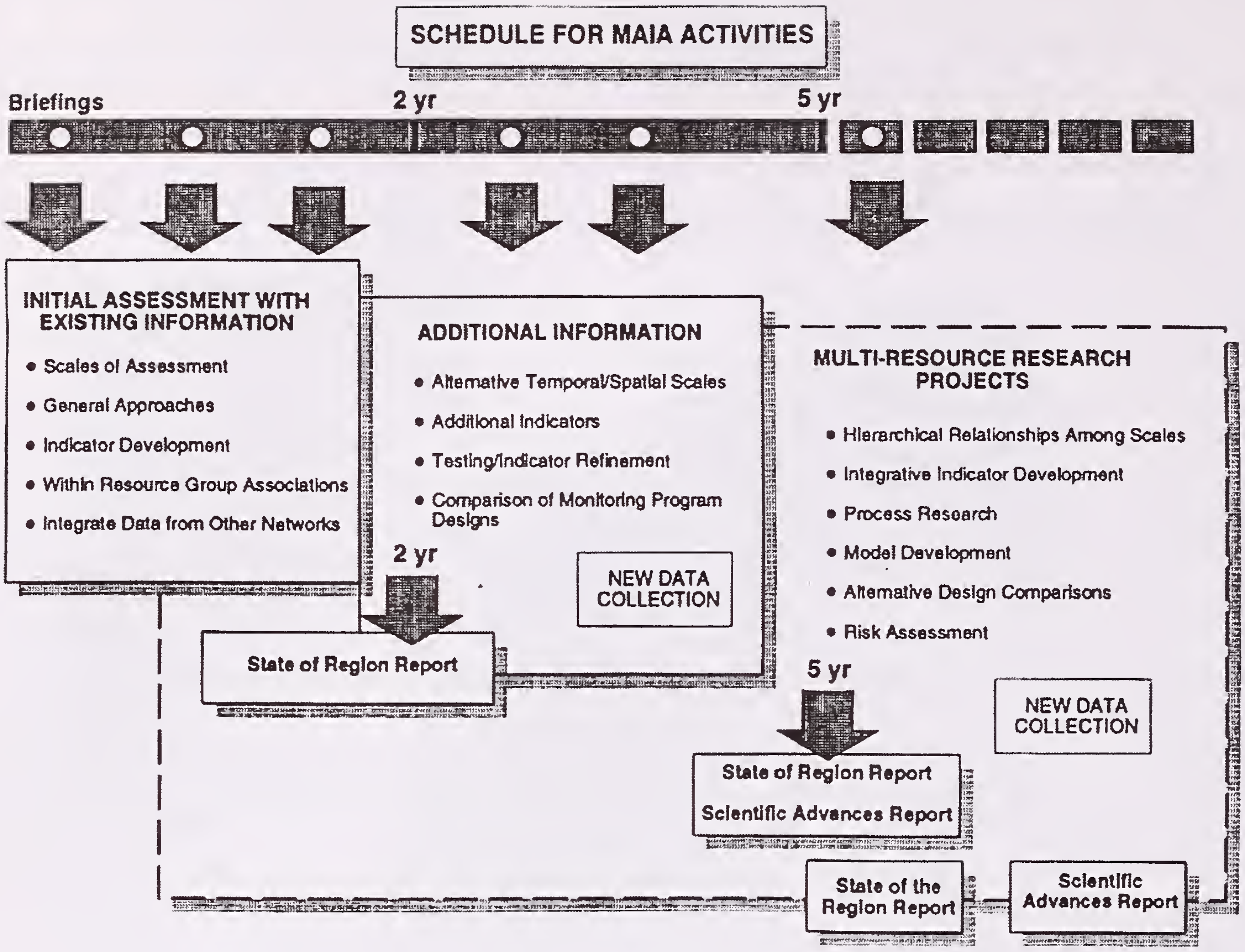

Figure 6. Schedule for MAIA activities.

- Level two — within-resource associations for a single resource group in the mid-Atlantic or selected subregions.
- Level three — Landscape assessments - determining landscape condition and the associations between resource condition and landscapes.
- Level four — Multiple resource assessments - determining relationships among resources at various spatial scales.

Integration in the assessment results proceeds by the bottom-up approach beginning with within-resource associations, then resource-landscape associations, and finally cross-resource associations. Integration is also achieved through the top-down approach of assessing landscapes at a hierarchical level about individual resources.

PRODUCTS OF MAIA

It is envisioned that MAIA will produce two different, but related, kinds of reports: (1) "State of the Region" reports that describe the condition (status) of biological resources within the MAIA; and (2) a report on "Scientific Advances for Future Monitoring and Assessment" that documents recommendations for a monitoring system that can provide scientifically sound, integrated assessments of ecological condition to meet the future needs of resource managers (Table 2).

The State of the Region reports will be produced on an indefinite 3-year cycle (beginning at years 2 and 5) through the process developed by MAIA. Regular 6-month briefings of Region III managers will ensure that interim results will improve environmental decision making (Figure 6). It is expected that an initial

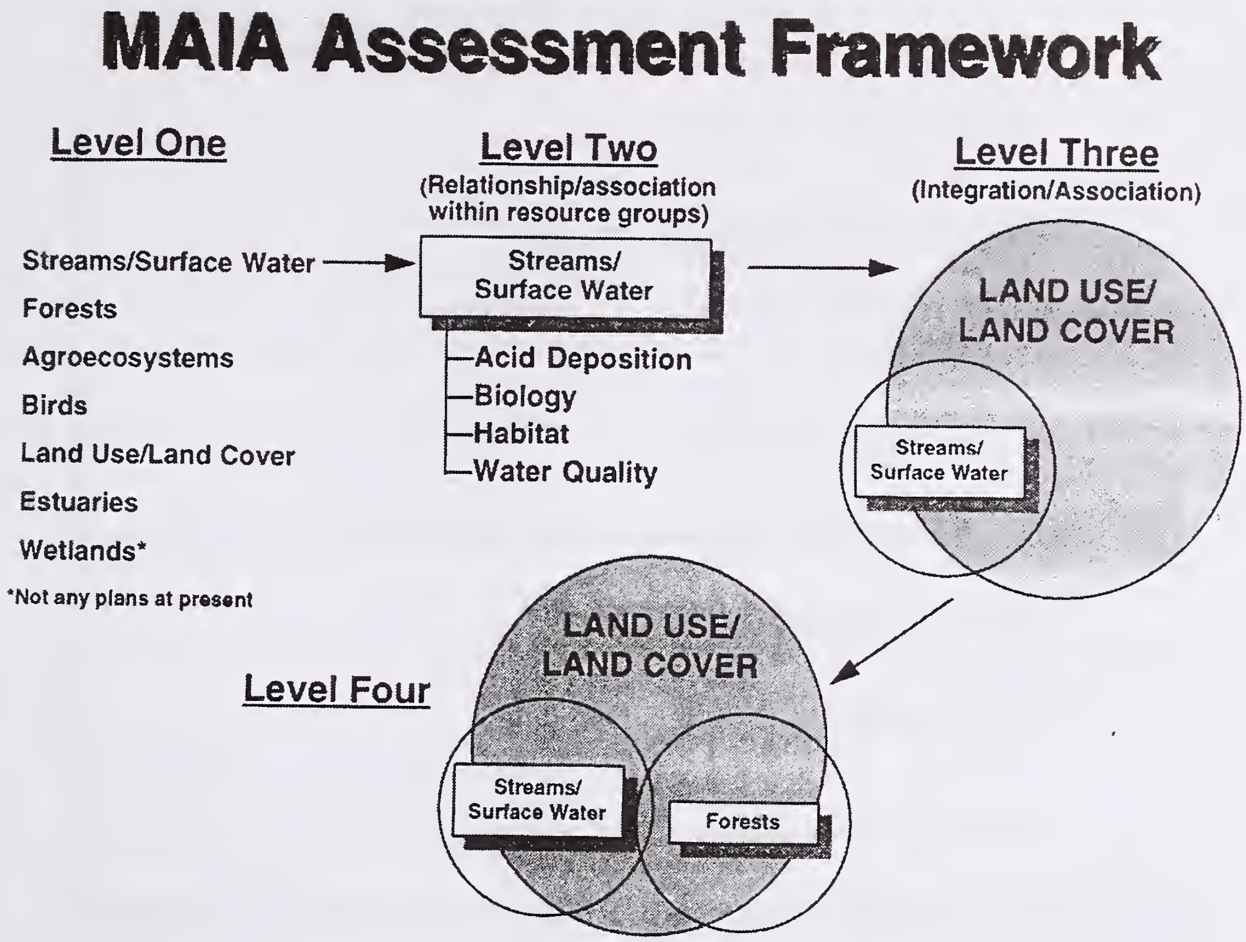

Figure 7. Mid-Atlantic integrated assessment (MAIA) Assessment Framework.

report will be produced in 1997 and will be limited to currently available data and methods. The second report will be produced in 2000 and will include additional data, new indicators, and revised methods developed over the next five years. Landscape-level information will figure prominently in this report. Future State of the Region reports will be enhanced by implementation of the recommendations in the Scientific Advances for Future Monitoring report and will draw upon results from the long-term research on multiple resources.

It is envisioned that the Scientific Advances for Future Monitoring report will be completed in 2000. Peer review journal articles will also document the research results that will enhance EMAP and ensure that future implementation of the program injects the best science into environmental decision making. Region III managers, along with other interested environmental managers affiliated with MAIA, may find opportunities to change management plans as a result of findings presented in the Scientific Advances for Future Monitoring.

STATUS OF MAIA

A major reorganization has recently taken place within EPA's Office of Research and Development. As a result of this reorganization, primary responsibility for the ORD contributions to MAIA now resides with scientists within the Atlantic Ecology Division of the National Health and Ecological Effects Laboratory, based in Narragansett, Rhode Island, USA. Several individuals there are developing a spatially-oriented, multilevel, systems-based conceptual model of the biological and physical components of the MAIA area to identify major components of the system and linkages between components (Munns et al. 1996). Using this conceptual model, they plan to

PRODUCTS FROM MAIA

- State of the Region Assessment Reports
  - Year 2 Report
  - Year 5 Report
- 6-month Briefing Packages
- Report on Scientific Advances for Future Monitoring and Assessment
- Peer-reviewed Publications
- Synthesis Papers

Table 2. Products from MAIA.

evaluate components and linkages rich with existing information, identify major existing uncertainties, evaluate the strengths of the linkages, and relate these linkages to primary management issues in Region III.

The Mid-Atlantic Highlands Assessment

Background

EPA Region III with the Office of Research and Development (ORD), Office of Water (OW), Office of Air and Radiation (OAR), Office of Planning and Evaluation (OPPE), States of Pennsylvania, West Virginia, Maryland, and Virginia, and nine (9) other federal agencies began an initiative in Mid-Atlantic Highlands, in 1994, to establish a management and science framework for setting environmental priorities. This ecosystem-based framework is intended to integrate condition of individual ecological resources such as air, surface waters, and forests into a more comprehensive overall assessment of Mid-Atlantic Highlands that considers economic and environmental concerns. To achieve this, the Mid-Atlantic Highlands Assessment (MAHA) program has three major components:

(1) a monitoring dimension that provides data on the ecological resources at various geographic scales,
(2) a research dimension that establishes the good science foundation for understanding and predicting, and
(3) an assessment dimension that translates scientific results into information useful for decision-making.

MAHA is a multi-discipline, multi-media (ecological resources) monitoring and assessment program that will produce environmental and economic data for strategic and operational management of ecosystems throughout the Mid-Atlantic Highlands.

The assessment will integrate new monitoring data with select historical data to:

* assess the ecological status of resources

* report trends in resource conditions
* describe the relationships between ecological condition and pollutant stressors
* identify the likely causes of poor ecological condition
* help identify emerging problems
* evaluate the overall effectiveness of environmental management programs, and
* identify sensitive areas and species at risk.

The audience for the Highlands assessment includes:

- EPA Region III, both policy and program offices such as Water Division, Air and Hazardous, and Administration and Resource Management;
- States — New York, Pennsylvania, West Virginia, Maryland, Virginia, and North Carolina;
- other federal agencies — e.g., USDA/Forest Service, USDA/Agricultural Research Service, DOI/Fish and Wildlife Service, DOI/National Biological Service, DOI/National Park Service, DOI/Geological Survey, and universities/science organizations.

Stakeholders and Partnerships

EPA Region III has partnerships underway in MAHA with States, other federal agencies and public/private sources. The States were partners in the field monitoring design and collection phase and will be in data assessment as well. They will also be part of the Mid-Atlantic Highlands Coordinating Council (MAHCC), an institutional framework, formed by federal agencies, for regional cooperation and participation among federal agencies, States and public towards a collective and more holistic approach to the management, conservation and protection of Mid-Atlantic Highlands natural resources. The following federal agencies are already partners: Department of Interior/Office of Surface Mining, Department of Interior/National Park Service, Department of Interior/National Biological Service, Department of Interior/Fish and Wildlife Service, Department of Interior/Geological Survey, U.S. Department of Agriculture/Forest Service, U.S. Department of Agriculture/Natural Resources Conservation Service, U.S. Department of Agriculture/Agricultural Research Service, and U.S. EPA.

Many federal, state, and local agencies, public groups, and citizens are interested in ecosystem information, research, education, protection, conservation, and management, including restoration of the ecological resources of the Highlands. The ecosystem approach to management will require the combined and coordinated efforts of all these federal, state, local and private stakeholders. The stakeholders also include regional and interstate programs and authorities such as river basin commissions; regional planning authorities; academic institutions; environmental organizations; private entities; the public; and Congress. Several EPA policy and program offices are partners in MAHA as well. They include: Office of Water (OW), Office of Air (OANR), Office of Policy, Planning, and Evaluation (OPPE), Office of Administration and Resources Management (OARM), and Office of Prevention, Pesticides and Toxic Substances (OPPTS).

Geographic Location

The Mid-Atlantic Highlands, which extend east to west from the Blue Ridge Mountains to Ohio and north to south from New York to North Carolina/Tennessee, represent many unique terrestrial and aquatic ecosystems and include six major watersheds. The natural features of the Mid-Atlantic Highlands showcase both the complexity and connectivity of ecological systems, including the largest diversity of freshwater mussels found in the nation, some of the most diverse deciduous forests found in the world, and numerous geographically restricted flora and fauna species that are on the edge of their range or isolated genetically.

The study area is more than 65,000 square miles of oak-hickory and maple-beech forests and upland areas in the States of Virginia, West Virginia, Maryland and Pennsylvania with additional interest in connected States of New York to the north and North Carolina to the south. It includes the headwaters for six major watersheds: Potomac, Susquehanna, New, Kanawha, Allegheny, and Monongahela Rivers. Because of the range of ecological diversity represented within the Highlands, there are six distinct eco-regions which characterize the Highlands: western Allegheny Plateau, northern Appalachian Plateau and uplands, north central Appalachians, central Appalachian plateau, central Appalachian ridges and valleys, and Blue Ridge Mountains. Ecoregions are

geographic areas with common land forms, soils, geology, land use, and vegetation and are like a watershed, a management tool for targeted environmental protection efforts.

Major Environmental Problems

An important ecological resource for eastern U.S., the Mid-Atlantic Highlands provide habitat for many important and unique species. The Highlands are exposed to many environmental stressors, including:

(1) high rate of acid deposition and other air pollution,
(2) acid runoff from mining,
(3) soil erosion and stream siltation from mining, logging and new housing and recreation development,
(4) landscape fragmentation from community and recreation construction,
(5) habitat loss and change, and
(6) non-point runoff from agriculture and logging.

All impact the natural aquatic and terrestrial resources including fisheries and their habitat, recreational resources, forest and agricultural productivity, and wildlife habitat. The effects of these stresses are seen in diminished species diversity, declining natural productivity and impacts on unique biota and habitats. Degraded water quality from the streams and rivers of the Mid-Atlantic highlands will have direct effects on the Chesapeake Bay, the Great Lakes, and the Ohio and Mississippi River systems.

Environmental Goals

The goal of the MAHA program is to define the status and trends of ecological resources in MAHA in relation to "reference conditions": seek associations between resource conditions and land use, land cover and landscape patterns; identify impacts from pollutant stressors and recommend possible management action plans. It is designed to answer the key questions: what is the current condition, is it changing, what is causing it, what can we do about it, and are we making a difference?

The environmental goals of the MAHA program are to:

* establish environmental strategic priorities based on risk.
* rank problems according to severity.
* establish in-stream goals for clean-up activities that include water quality and biological criteria.
* establish optimum environmental conditions (reference conditions) to serve as baseline goals for watersheds and ecoregions preservation, restoration, and remediation.
* map areas of concern in need of special protective action, either for remediation or preservation.
* identify areas for priority joint management action with states, other federal agencies, and private organizations.
* evaluate effectiveness of Best management practices (BMP) on non-point source pollution.

These environmental goals will be further quantified, such as miles of streams restored to in-stream goals, acres of habitat restored, miles of acid streams restored from mine drainage, acres of landscape with better connectivity (not fragmented), and number of habitat gains i.e., acres of wetlands, etc. as the assessment results become available.

Strategic Goals

1. Determine state of ecological resources. The program will define the status and trends of ecological resources in relation to "reference conditions."
2. Determine impacts due to land use changes. Associations between resource conditions and land use, land cover and landscape patterns, will be determined to assess changes impacting current conditions.
3. Identification of pollutant stressor impacts.
4. Development of management action plans.

Environmental Measures/Monitoring Progress

Systematic collection of key environmental data began in 1994. The data covers the status of ecological condition of surface water streams including aquatic communities and habitats, forests, and agricultural systems as well as information on land use/land

cover, air deposition, and landscape patterns. MAHA emphasizes the use of environmental indicators as a basis for strategic planning and management. MAHA emphasizes biological indicators in contrast to the traditional approach of monitoring chemical and physical indicators only. The monitoring design for MAHA is based on a variety of indicators of biological condition, including the measurement of indicators at reference sites which reflect ideal conditions.

The surface water segment of MAHA includes measurements of benthic communities, macro-invertebrates, several fish samples, habitat condition, and physical and chemical water quality. MAHA will present integrated environmental analysis using a combination of these criteria.

Stressor indicators are characteristics of the environment that are suspected to elicit a change in the condition of an ecological resource, and they include both natural and human induced stressors. They will be pursued to determine, to the extent possible, the probable causes for observed conditions. We are using "diagnostic categories" which will encompass the full range of impacts to aquatic systems from: 1) chemical alterations, 2) hydrologic alterations, 3) physical habitat alterations, to 4) biological alterations.

These stressor indicators will be measured at the stream scale and at the watershed scale. Many of the watershed scale measures will come from data sources such as remote sensing platforms (for land use and land cover) and existing data bases (various point source data bases maintained by EPA and the states). MAHA will show these associations and linkages between the status of resources and external stresses. These associations can provide insight to the environmental manager and support assessment of comparative risks and effective management of ecosystems. Information generated will help identify areas of concern and suggest strategies for addressing highest priority problems.

MAHA ecological data will also be overlaid, using GIS, on a variety of other information such as land use/land cover, ecoregions, hydrologic basins, and point source discharge data bases to create a watershed characterization and association with streams ecological condition within the Mid-Atlantic Highlands area. Thus, we will have an image of stream segments and the watersheds which influence them. This will facilitate evaluation of the extent to which watershed characteristics and activities impact biological integrity within streams. It will also provide an enormously rich dataset from which we can begin to evaluate patterns in watershed types and characteristics.

Science/Data and Multi-Media Assessment

Key environmental data are being collected on the conditions of surface water streams, including associated aquatic communities and habitats; forests; agricultural systems; land use/land cover; air deposition; and landscape patterns. Biological and habitat indicators will be developed and applied. Analyses are integrating the use of Geographic Information Systems and landscape ecology techniques to explore the complex issue of biodiversity and support watershed, ecosystem and eco-region-based analyses. Integrated assessments, using comparative-risk based techniques will be utilized.

Education and Outreach

The MAHA program held an October '95 conference to begin receiving public input on their values, visions and needs for the Highlands. Natural features of this region illustrate both the complexity and connectivity of ecological systems. The region's streams, for example, are inhabited by the largest diversity of freshwater mussles found in the world. The region's watersheds contain some of the most diverse deciduous forests found in the world. Within these ecosystems, there are species of animals that are found nowhere else on earth.

The region is accessible in a day's drive to well over a third of the population of the United States. The growing population and associated development in and around the Highlands can be expected to stress its ecosystems and nearly pristine habitats. The Mid-Atlantic Highlands states are dependent on the extraction/removal of its resources for their economic well being, further stressing these ecosystems. Mine drainage and wastewater loads are just two examples of severe stressors to the mineral extraction. It is imperative that the public, private and local

government stakeholders of the Highlands work in a focused and comprehensive way toward both economic and environmental sustainability.

EPA has asked the Conservation Fund and its Freshwater Institute to explore development of a Canaan Valley Institute for the Highlands. The Canaan Valley Institute for the Mid-Atlantic Highlands [interim name] will bring together a consortium of public and private interests to work on short- and long-term aquatic and terrestrial resource initiatives and issues of the Mid-Atlantic Highlands under one formal and focusing organization. The Institute will coordinate with programs of the various public and private entities now working on the Mid-Atlantic Highlands and those that will be in the future. The Institute will be governed by representatives of the region's stakeholders and will work with the stakeholders, including local governments, in identifying needs and information gaps; collecting data and other information; and, developing and implementing solutions. Accomplishing the mission of promoting management and protection of the Highlands' resources and aquatic habitats requires an apolitical nongovernmental nonprofit organization that is responsive and accountable to the regional stakeholders. That organization is the Institute.

The Institute will also assist MAHA in public outreach and education. With the help of the Institute, all stakeholders can be enlisted— those citizens within the communities who have a stake in the ecological and economic viability of a region— to help set measurable goals. People are an integral part of an ecosystem and they must participate in any strategic choices about its management. Partnerships will be forged between the natural resources and economic development communities for cooperative problem solving and strategic planning.

CONCLUSION

The signing of The Highlands Accord (Memorandum of Understanding 1995) signals the start of renewed cooperative efforts within the western half of the MAIA region. The MAHA Council has articulated its desire to work closely with state entities in sharing information, as well as in using that information for development of more environmentally-sensitive management plans. For some people, The Highlands Accord signifies a heightening of awareness of the need to protect, conserve, and manage the resources of the Mid-Atlantic Highlands to the point that the information available to MAHA managers will be comparable to that available to their counterparts in the eastern half of the MAIA region along the Atlantic coastline.

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The Use of Resource Inventories for the Evaluation of Threats to Ecosystems and Protection of the Environment

Terence P. Boyle[1]

Abstract.—Strategies for the use of resource inventories for the preservation of threatened ecosystems include classification and characterization of critical ecological components, and the evaluation of the nature of threats to these systems. Currently, resource inventories are being conducted at different levels of effort for a variety of reasons, including lists of species from biological surveys and determination of the geographical extension of significant associations of plants and animals, evaluation of populations of species that constitute important resources, such as timber surveys, evaluation of grassland communities for grazing, and stock assessment of commercially important fish.

Methods of analysis of risk due to contamination by toxic chemicals have been developed using laboratory toxicity tests. Nevertheless, these tests are not able to make accurate predictions at the level of community or ecosystem. Moreover, other anthropogenic factors such as changes in land use, destruction of habitat, introduction of exotic species, and changes in climate that threaten entire ecosystems are not predicted by traditional techniques of toxicological risk assessment.

The concept of ecological risk analysis is based on two premises: 1) it is impossible to prevent all the environmental effects due to development, and 2) the management and protection of natural resources is necessarily based on incomplete scientific information. A method to develop ecological risk analysis using resource inventories consists first in defining ecological health in terms of sustainability, and defining critical attributes at the level of community and ecosystem in order to maintain ecosystem health. Examples of these attributes includes the dynamics of critical nutrients and energy, trophic structure, biodiversity, condition and genotypic diversity of key species, patterns of dispersion and migration, and stage of ecological succession. Secondly, these critical ecological attributes should be amenable to analysis in relation to the sensitivity of the ecosystem to expected anthropogenic stress and comprised of specific selected parameters on a regional basis for monitoring. The maximum and minimum tolerable values for each index monitored should be determined to provide a diagnostic capacity and predict various levels of stress to the ecosystem. Finally, measurement endpoints should be formulated into a monitoring program that would allow timely evaluation of the status of ecological resources.

INTRODUCTION

At present, regions where development is accelerating encounter serious problems that affect the quality of the environment and the status of natural resources. These problems include large scale changes in land use, contamination of entire aquatic and terrestrial ecosystems, regional contamination of the air, coastal degradation, loss of wetlands, introduction of exotic species, loss of biodiversity, and climatic

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changes induced by man. All these problems cause the degradation of the environment over a long time period and at a large scale. Ecosystems of great value such as large lakes, deep rivers, estuaries, and even entire biogeographic regions are being subjected to multiple anthropogenic perturbations. The effective management of natural resources over long time periods and at large scale requires new strategies for the evaluation and integrated monitoring of the environment (Odum, 1993).

This paper provides a general strategy for ecological risk analysis using resource inventories and categorizes the type of information necessary to provide critical knowledge over an ecological data base that allows evaluation of the impact in the early stages of anticipated development. This strategy supposes that ecologists understand, at least in principle, the ecological basis of support for natural resources and the importance for application of ecological principles for managing these resources. Some forms of regional economic development are inevitable. Nevertheless development should not take place at the expense of existing natural resources. Evaluation of threats to ecosystems and their resources should be part of the process of planning for those in charge of regional development and managers of resources.

RISK ANALYSIS

Analysis of risk in the medical sciences has concentrated in the past on factors that directly affect human health and mortality. For example one can calculate the risk due to cigarettes, the use of certain medicines, or the construction of nuclear power plants. In the field of environmental sciences, risk analysis has been applied to the use of pesticides and the discharge of industrial chemicals based on calculations of the fate of these chemicals in the environment and batteries of laboratory toxicity tests in order to estimate the effects of chemicals on important representative species (USEPA, 1992). These methods of evaluation, however, are not able to calculate the indirect effects on other organisms, the effects at higher levels of organization, such as community or ecosystem, and are not able to estimate the effects on non-chemical stress and the impacts of multiple chemical effects (Bartell et al, 1992).

Ecological risk analysis supposes that, 1) the elimination of all effects of development is impossible, and 2) the management and protection of natural resources is made on the basis of incomplete scientific information (Suter, 1993). The stratagem elaborated here would extend and incorporate information derived from resource inventories into a risk analysis scheme in order to identify changes before damage has occurred at a large scale. The information would be used to predict the final changes and to plan for mitigation of potential ecological damage. This type of evaluation is retrospective and retroactive in the sense that it appraises changes that have already occurred; however, it is also prospective and proactive in that it uses estimates of change in the early steps of degradation and ecological knowledge from the inventory in order to estimate the final stage of a resource or ecosystem due to the impact of development. The condition of the resource or ecosystem due to the impact is the point of departure for this analysis.

INVENTORIES AND RISK ANALYSIS

Natural resource inventories in the past have dealt with making catalogues of existing species and establishing the limits of their geographic distribution (Kim and Knutson, 1986), and the assessment of items of major resource value, such as the volume of wood in timber surveys (Lund, 1986), evaluation of the condition of grassland communities for grazing (Breckinridge et al, 1995), or assessment of the stock or number of fish (Charles, 1994). However, these inventories are also able to provide critical elements in a program of risk analysis if they include an ecological perspective and entail the following steps:

1) Definition of ecological health;
2) Characterization of regional profiles of ecological health in terms of critical ecological attributes, and
3) The formation of ecological end points that can be measured in order to determine the health of the ecosystem and provide a basis for monitoring.

Ecological Health

The health of an ecosystem can be characterized considering the age or stage in succession of the ecosystem (Odum, 1969). Ecosystems in the early stages of succession will have different characteristics and greater susceptibility to threats than those more mature. In practice, the concept of health of an

ecosystem should include determination of keystone species and critical communities, and not the evaluation of an overwhelming number of species (Cairns, et al, 1993; Nip and Udo de Haes, 1995). This will require knowledge of the local or regional ecology, critical judgement, and prioritization by ecologists conducting the inventories.

Characterization of the concept of ecological health should be derived from knowledge of ecological theory and should include an array of physical, chemical, and biological attributes directly responsible for the existence and sustainability of the ecosystem (Shaeffer et al 1988). The physical availability of habitat is a necessary precursor for the presence and survival of organisms. There certain critical minimum requirements of habitat for many species or communities below which they are not able to exist. For example, if wetlands are drained or destroyed, there can be no wetland species or communities. Certain forms of energy such as adequate sunlight, various forms of chemical energy, physical energy such as wind or water currents, are also critical for the existence of certain organisms. Over all, large scale changes in land use, for example forest or wetland to agriculture, are so destructive of habitat that minimum requirements of species or communities should be determined scientifically.

Chemical characteristics of ecosystem health include adequate inorganic nutrients to maintain the biological community. These nutrients include, not only those commonly associated with primary productivity, but those required by animal nutrition as well. Moreover, not only the presence of adequate amounts is important, but their cycling through the system and biological availability as well.

Biological qualities indicative of ecosystem health include: 1) genotypic and phenotypic diversity adequate to sustain and perpetuate organisms, 2) a robust food web to maintain the structure of the community, 3) feedback mechanisms to reduce disruptive oscillations, 4) the ability to either decompose toxic chemicals or to bind them so that they remain unavailable to biological organisms, and 5) the degree of functional redundancy of a system (Barnthouse et al, 1991).

These physical, chemical, and biological characteristics should be evaluated to characterize the vulnerability of different types of ecosystems to various forms of stress. The ability to metabolize toxic chemicals is due to a range of physical, chemical, and biological characteristics characteristic of various types of ecosystems. This ability imparts a certain ecological inertia to stress (Westman, 1978) that is important in the evaluation of risk. The functional redundancy of an ecosystem implies a number of species present that are able to perform the same tasks within the system. For example, there may be a number of species that feed in a like manner (e.g. herbivores, carnivores, detritivores) that can replace one another functionally if one species is unable to function due to stress. Mature, complex ecosystems with a high degree of functional redundancy are ecosystems with inertia or a resistance to stress that would severely impact other simpler ecosystems (Odum, 1969).

Regional Profiles of Ecological Health

In defining ecological health on a regional basis, an analogy to characterizing human health is useful. Human health may be defined as the condition of the body as determined by a number of parameters such as body temperature and structural integrity, height-weight relationship, the chemical condition of blood and other body fluids that are parameters of the biological condition of various organ systems, etc. Measurements of these critical health attributes within certain ranges are considered healthy. When these limits are exceeded the individual is considered diseased or unhealthy, and some sort of medical action is warranted.

In order to use ecological theory to expand the interpretability and use of resource inventories it is useful to introduce the term ecological paradigm, which is defined as a specific model or set of hypothesis encompassing comprehensive characterization of resources at the population, community, or ecosystem level of organization. Ecological theory provides the basis for management, diagnosis and treatment of the ecosystem in the same fashion the human anatomy and physiology provides the basis for the practice of human medicine. The selection and application of the ecological paradigm depends on the management questions asked in planning the inventory. For example, single species populations routinely inventoried include major resource organisms such as commercially important fisheries or trees valued for timber, pest species, important charismatic megafauna, or endangered species. There are ecologically interpretable population models that incorporate reproduction, growth, and survival; life tables in the form of

Leslie matrix; analysis of population structure (ie size, age, sex); and assessments of the importance of interrelations with other species (i.e., predation, competition, parasitism, mutualism, etc.).

Inventories at the community level are commonly done to classify forest types, to conduct vegetation analysis, to identify baseline data to establish biogeographic regions, and to asses environmental impact. Community level ecological paradigms include successional models and the establishment of criteria for climax communities, various types of community structural analysis such as diversity, dominance, similarity, stability, measurement of primary or secondary production or yield, and various aspect of biogeography such as immigration/extinction ratios and species equilibrium.

Examples of paradigms at the ecosystem level are the River Continuum Concept (RCC) (Vannote et al, 1980) which describes how physical, chemical, and biological conditions change as a small streams become larger and larger eventually becoming a large river. Important aspects of the RCC include watershed area and hydrological discharge, functional group analysis (feeding guilds) of fish and benthic invertebrates whose ecological role changes with changes in stream size, changes in the pattern and importance of detrital organic carbon, the relative role of photosynthesis and the periphyton/phytoplankton communities, nutrient loss, and discontinuity within the longitudinal ecological succession of a river due to anthropomorphic disruption.

Inventories of lake ecosystems can be facilitated by considering the trophic succession model (oligotrophic, mesotrophic, eutrophic, or hypertrophic), limiting nutrient, nutrient loading chemical classification, and by key physical attributes such as depth, volume, surface area, dynamics of mixing, formation and depth of thermocline (Wetzel, 1982).

The use of regional frameworks is important in the subdivision of broad geographical efforts in both management of natural resources and environmental protection. (Gallant et al, 1989; Omernik and Griffith, 1991)). An explicit geographical framework for assigning critical ecological characteristics within regions to determine ecological health has been proposed by Omernick (1987). Certain limits of these ecological characteristics within defined ecological regions should have certain expected limits that can be used for regional risk analysis (Grahm et al, 1991; Hunsaker et al , 1990). The organization of resource inventories into regional patterns would yield a data base that could be used to define the bounds of selected ecological variables to determine ecological health.

Ecological Enpoints

In a fashion similar to human medicine approaches, sets of ecological endpoints should be formulated from the formal theory in ecological paradigms. An ecological endpoint is defined as an ecological parameter whose normal operating limits can be determined for the ecosystem in question (Suter 1990). A major effort in ecosystem risk analysis is the identification of appropriate ecological endpoints that are indicators of ecological health and sensitive to early stages of anthropomorphic change. In order to relate to human society these ecological endpoints should be associated with social, cultural, or economic consequences. For example, the uncontrolled development of mining may damage water quality which will cause a loss of a commercial fishery. The application or excessive use of certain types of pesticides may cause the extinction of charismatic megafauna of national importance. From an operational aspect, ecological endpoints should be easily measured, quantifiable, and amenable to statistical analysis. They should be sensitive to early or defined status of ecological stress to allow for mitigation measures to be employed.

Examples of endpoints include quantitative estimates of density of commercially important species or charismatic megafauna, the status of an introduced pest species on a large scale, changes in the concentration of critical nutrients (either additions or losses), especially those nutrients such as nitrogen and phosphorus known to control primary production, and measure of community structure such as density, species richness, diversity, similarity, and dominance.

Ecological endpoints can be arranged in profiles to characterize and monitor through time the ecological health of the resource and ecosystem in question. Some research in determining appropriate ecological endpoints, statistical properties, and required measurement frequency are necessary.

SUMMARY

The model that is proposed here for the development and use of resources inventories is presently in use for aquatic natural resources in National Parks in the United States (Boyle et al, 1991). Attributes of these programs may find applicability other areas and countries. Eugene Odum (1975) has characterized ecology as the bridge between the social and environmental sciences. The form in which environmental data will be used determines how the data will be collected. How the inventories are used depends on the system of values of the country and the region, its economic situation, its customs, practices, and laws. What is important is the formulation of a strategy that is appropriate and a program of collection of data on resource inventories that has broad ecological applications for the management of resources and the protection of the ecosystem.

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El Uso de Inventarios de Recursos para la Evaluación de Amenazas a Ecosistemas y la Protección del Ambiente

Terence P. Boyle Ph.D.[1]

Resumen.-Las estrategias para el uso de inventarios de recursos para la preservación de ecosistemas en peligro incluyen la clasificación y la caracterización de los componentes ecológicos críticos de dichos ecosistemas, y la evaluación de la índole de las amenazas. En estos momentos se están conduciendo inventarios con una variedad de propósitos a diferentes niveles de esfuerzo. Estos incluyen listas de especies de relevamientos biológicos y identificación de la extensión geográfica de asociaciones importantes de plantas y animales, la evaluación de poblaciones de especies que constituyen recursos importantes como inventarios de maderas, la evaluación de comunidades de praderas para el pastoreo, y de las especies de peces de valor comercial importante. Los métodos de evaluación de riesgo debido a la contaminación tóxico-química han sido bien desarrollados usando pruebas de toxicidad en laboratorios. Sin embargo, dichas pruebas no pueden predecir con exactitud al nivel de comunidad o al de ecosistema. Además hay otros factores antropogénicos, como el cambio en el uso de la tierra, la destrucción del habitat, la introducción de especies exóticas, y las variaciones climáticas que amenazan a ecosistemas completos, las cuales no pueden ser predichas por medio de las técnicas tradicionales de evaluación de riesgos biotoxicológicos.

El concepto de análisis de riesgo en un ecosistema se basa en dos suposiciones: 1) es imposible eliminar todos los efectos ambientales debidos al desarrollo, y 2) el manejo y la protección de los recursos deben basarse en información científica incompleta. Para desarrollar técnicas de análisis de riesgo en ecosistemas utilizando inventarios de recursos se debe primero, definir la "salud del ecosistema" en términos de sostenibilidad y definir los atributos críticos al nivel de comunidad y ecosistema necesarios para el mantenimiento de dicha salud. Ejemplos de estos atributos incluyen la dinámica de nutrientes críticos y de energía, la estructura trófica, la biodiversidad, la condición y diversidad genética de especies claves, los patrones de dispersión y migración, y la etapa de sucesión ecológica. Como segundo paso, estos atributos críticos pueden ser analizados en relación a la sensibilidad del ecosistema a probables disturbios antropogénicos que incluyen a parámetros específicos elegidos sobre una base regional para su monitoreo. Por último, deben determinarse los valores máximos y mínimos tolerables para cada índice de monitoreo de modo de proveer capacidad de diagnóstico y pronóstico a varios niveles de perturbación sobre el ecosistema.

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INTRODUCCIÓN

Hoy en día regiones donde el desarrollo se está acelerando enfrentan serios problemas que afectan al medio ambiente y a la condición de los recursos naturales. Estos problemas incluyen cambios en gran escala en el uso de la tierra, compleja contaminación química de ecosistemas acuáticos y terrestres enteros, contaminación regional del aire, degradación costera, pérdida de pantanos, introducción de especies exóticas, pérdida de biodiversidad, y cambios climáticos inducidos por el hombre. Todos estos problemas causan la degradación del medio ambiente a largo plazo y en gran escala. Ecosistemas de gran envergadura como grandes lagos, ríos caudalosos, estuarios y aún regiones biogeográficas enteras están siendo sujetas a múltiples perturbaciones antropogénicas. El manejo efectivo de los recursos naturales a largo plazo y en gran escala requiere nuevas estrategias para la evaluación y el monitoreo integral del medio ambiente (Odum, 1993).

Este trabajo provee una estrategia general para el análisis de riesgo ecológico usando inventarios de recursos y categoriza el tipo de información necesaria para suministrar conocimiento crítico sobre una base ecológica que permita evaluar el impacto del impacto durante las primeras etapas del desarollo anticipado. Esta estrategia asume que, como ecologistas entendemos, por lo menos en principio, la base ecológica de apoyo para los recursos naturales y la importancia de la aplicación de principios ecológicos para el manejo de recursos. Algunas formas de desarrollo económico regional son inevitables. Sin embargo, el desarrollo no debe llevarse a cabo a expensas de los recursos naturales existentes. La evaluación de las amenazas a ecosistemas y sus recursos debe ser parte del proceso de planificación de los encargados del desarrollo regional o administradores de recursos.

EL ANALISIS DE RIESGO

El análisis de riesgo en las ciencias médicas se ha concentrado en el pasado en factores que afectan directamente a la salud humana y la mortalidad. Por ejemplo, se puede calcular el riesgo debido al uso de cigarrillos, al uso de ciertos medicamentos, o a la construcción de plantas nucleares. En el campo de las ciencias del medio ambiente el análisis de riesgo ha sido aplicado al uso de pesticidas y a la descarga de productos químicos industriales usando cálculos del destino de los productos químicos en el medio ambiente y baterías de pruebas de toxicidad en laboratorios para estimar los efectos directos de dichos productos en representantes de especies importantes (USEPA, 1992). Estos métodos de evaluación, sin embargo, no pueden calcular los efectos indirectos sobre otros organismos, los efectos a niveles de organización más altos, como la comunidad o el ecosistema, y tampoco pueden estimar los efectos de productos no-químicos y los de impactos químicos múltiples (Bartell et al, 1992).

El análisis de riesgo a ecosistemas asume que, 1) la eliminación de todos los efectos del desarrollo es imposible, y 2) el manejo y la protección de los recursos deben hacerse con información científica incompleta (Suter, 1993). Este planteo extendería e incorporaría la información derivada de los inventarios de recursos a un esquema de análisis de riesgo a ecosistemas para identificar cambios antes de que daño a gran escala haya ocurrido. La información podría ser utilizada para predecir los cambios finales y para planear la mitigación del daño ecológico potencial. Este tipo de evaluación es retrospectiva y retroactiva en el sentido en que estima cambios que ya han ocurrido; sin embargo, también es prospectiva y proactiva porque usa estimaciones de cambio en las primeras etapas de degradación y el conocimiento ecológico de inventarios para estimar la etapa final de un recurso o ecosistema debido al impacto del desarrollo. La condición del recurso o ecosistema debido al impacto, en vez de la fuente de amenaza, es el punto de partida para el análisis.

LOS INVENTARIOS Y EL ANALISIS DE RIESGO

Los inventarios de recursos naturales en el pasado han tratado de hacer catálogos de especies existentes, establecer su distribución, los límites de su extensión geográfica (Kim and Knutson, 1986), y la evaluación del número de especies de recursos mayores, como el volumen de maderas (Lund, 1986), la evaluación de la condición de comunidades de pradera para el pastoreo (Breckinridge et al, 1995), o el número de peces (Charles, 1994).

Sin embargo, los inventarios también pueden proveer elementos críticos en un programa de análisis de riesgo si incluyen una perspectiva ecológica y si tienen presentes los siguientes pasos:

1) La definición de la salud del ecosistema;
2) La caracterización de perfiles regionales de la salud de ecosistemas en términos de atributos ecológicos críticos, y
3) La formulación de puntos finales ecológicos que puedan ser medidos para determinar la salud ecológica y proveer una base para el monitoreo.

La Salud Ecológica

La salud de un ecosistema puede ser caracterizada en base a consideraciones sobre la edad o etapa de sucesión del ecosistema (Odum, 1969). Ecosistemas en las primeras etapas de desarrollo van a tener diferentes características y mayor susceptibilidad a amenazas que los más maduros. En la práctica el concepto de salud del ecosistema debe incluir la identificación de especies claves y comunidades críticas y no la elaboración y evaluación de un número abrumador de especies (Cairns et al, 1993; Nip and Udo de Haes, 1995). Esto va a requerir conocimiento de la ecologíca local o regional, razonamiento crítico y la selección de prioridades de parte de los ecologistas haciendo los inventarios.

La caracterización del concepto de salud de un ecosistema debe ser derivado a través del conocimiento de la teoría ecológica y debe incluir un número de atributos físicos, químicos y biológicos directamente responsables por la existencia y la conservación del ecosistema (Shaeffer et al; 1988). La disponibilidad física del habitat es un precursor necesario para la presencía y la supervivencia de organismos. Hay requisitos críticos mínimos en habitats para muchas especies o comunidades bajo los cuales no pueden subsistir. Por ejemplo, si no hay humedales no puede haber especies o comunidades de humedales. Ciertas formas de energía como adecuada luz solar, varias formas de energía química, energía física como el viento o corrientes de agua, también son críticas para la existencia de ciertos organismos. Sobre todo, cambios en el uso de la tierra a gran escala, por ejemplo, de bosque a agricultura, son tan destructivos que requisitos mínimos de habitat para especies o comunidades deben ser determinados científicamente.

Las características químicas de la salud de un ecosistema incluyen adecuados nutrientes inorgánicos para mantener la comunidad biológica. Estos nutrientes incluyen, no solamente esos comúnmente asociados con la productividad primaria, pero también los necesarios para la nutrición animal. Además es importante tanto la presencia de nutrientes adecuados como así también su reciclamiento a través del sistema y su disponibilidad biológica.

Cualidades biológicas indicativas de la salud del ecosistema incluyen:

1) diversidad fenotípica y genotípica adecuada para mantener y perpetuar a organismos,
2) una cadena trófica para mantener la estructura de la comunidad,
3) un mecanismo de retro-alimentación para reducir las oscilaciones disruptivas,
4) la capacidad de descomponer productos químicos tóxicos o ligarlos para que se mantengan no-disponibles para los organismos biológicos, y
5) el grado de redundancia funcional de un sistema.

Estas características físicas, químicas, y biológicas deben ser evaluadas para caracterizar la vulnerabilidad de diferentes tipos de ecosistemas a varias formas de impacto. La habilidad de metabolizar los productos químicos tóxicos se debe a una gama de características físicas, químicas y biológicas típicas de varios tipos de ecosistemas. Esta habilidad imparte una cierta inercia ecológica que impacta (Westman, 1978) lo que es importante en la evaluación de riesgo.

La redundancia funcional de un ecosistema implica un número de especies presentes que son capaces de desempeñar las mismas funciones dentro del sistema. Por ejemplo, ciertas especies que se alimentan de la misma manera (ej., herbívoros, carnívoros, detrívoros) pueden reemplazarse a si mismas funcionalmente si una especie no puede funcionar debido a ciertas amenazas. Ecosistemas complejos y maduros con un alto nivel de redundancia funcional proveen inercia o resistencia a amenazas que podrían afectar muy severamente a ecosistemas más simples (Odum, 1969).

Perfiles Regionales de La Salud Ecológica

Para definir la salud de un ecosistema en una base regional se puede usar una analogía a la salud humana. La salud humana puede definirse como la condición del cuerpo determinada por un cierto número de parámetros o características físicas, como la integridad estructural del cuerpo, la relación entre el peso y la

altura, la temperatura; la condición química de la sangre y otros fluídos del cuerpo que son parámetros de la condición biológica de los varios sistemas orgánicos. Dentro de ciertos límites los valores de estos atributos críticos de la salud son considerados saludables , pero cuando estos límites se exceden el individuo es considerado enfermo o no-sano, y algún tipo de acción médica se recomienda.

Se puede usar la teoría ecológica para extender la interpretabilidad y el uso de los inventarios de recursos. Es útil para ello introducir el término paradigma ecológico, el que se puede definir como el modelo específico o grupo de hipótesis que cubre la caracterización comprensiva de recursos al nivel de población, comunidad o ecosistema. La teoría ecológica provee la base para el manejo, diagnosis, y tratamiento del ecosistema en la misma manera en que el conocimiento de anatomía y fisiología provee la base para la práctica de la medicina. La selección y aplicación del paradigma ecológico depende de las cuestiones de manejo y administración que surgen al planearse el inventario. Por ejemplo, poblaciones de especies únicas que se inventorean de rutina incluyen organismos considerados recursos importantes como la pesca o la madera, especies pestes, megafauna carismática e importante, o especies en peligro. Hay modelos de población que son ecológicamente interpretables que incorporan reproducción, crecimiento, y supervivencia; tablas de vida en forma de matrices de Leslie; análisis de la estructura de la población (ej., tamaño, edad, sexo) y evaluación de la importancia de las interrelaciones con otras especies (ej., depredación, competición, parasitismo, mutualismo, etc).

Inventarios al nivel de la comunidad están hechos comúnmente para clasificar tipos de bosques, analizar vegetación, proveer datos de base para establecer regiones biogeográficas, y evaluar el impacto ambiental. Paradigmas ecológicos al nivel de comunidad incluyen modelos de sucesiones y la identificación de criterios para comunidades clímax, varios tipos de análisis estructurales de la comunidad como diversidad, predominación, semejanza, estabilidad, medida de producción primaria o secundaria o cosecha, y varios aspectos de biogeografía como la proporción de inmigración y/o la extinción y el equilibrio de especies. Ejemplos de paradigmas al nivel de ecosistema son el concepto del río continuo (RCC) (Vannote, 1982) que describe los cambios en condiciones químicas, físicas y biológicas cuando un pequeño arroyo se agranda y finalmente se convierte en un río caudaloso. Importantes aspectos del RCC incluyen la superficie de cuenca y el descargo hidrológico, el análisis de grupos funcionales (asociaciones de alimentación) de peces y invertebrados bénticos, cuya parte ecológica cambia con cambios en el tamaño del arroyo, cambios en el patrón e importancia del detrito de carbón orgánico, la parte relativa de fotosíntesis y de las comunidades de perifitón y fitoplankton, la pérdida de nutrientes, y la discontinuidad en la sucesión ecológica longitudinal de un río debido a la intervención antropogénica.

Inventarios de ecosistemas lacustres pueden ser facilitados si se considera el modelo de sucesión trófica (oligotrófico, meso-trófico, eutrófico, o hipertrófico), limitación de nutrientes, clasificación química de cargas de nutrientes, y atributos físicos claves como profundidad, volumen, superficie, dinámica de mezcla, formación y profundidad del termoclima (Wetzel, 1982).

El use de patrones regionales es importante para la subdivisión de esfuerzos geográficos amplios tanto en el manejo de recursos naturales como en la protección del medio ambiente (Gallant et. al., 1989; Omernick and Griffith, 1991). Un patrón geográfico explícito para asignar características ecológicas críticas dentro de regiones para determinar la salud ecológica ha sido propuesto por Omernick (1987). Ciertos límites de estas características ecológicas definidas deben tener ciertos límites esperados que se pueden usar para el análisis de riesgo regional (Grahm et. al., 1991; Hunsaker et. al., 1990). La organización de recursos de inventarios en patrones regionales podría producir una base de datos que se podría usar para definir los límites de variables ecológicas seleccionadas para determinar la salud del sistema.

Puntos Finales Ecológicos

De una manera similar a los planteos de la medicina donde el diagnosis de atributos claves permite crear un perfil de la salud, grupos de puntos finales ecológicos deben ser derivados de la teoría formal como paradigmas ecológicos. Un punto final se define como un parámetro ecológico cuyos límites normales de operación pueden ser determinados para el ecosistema en cuestión (Suter, 1990). Un gran esfuerzo en el análisis de riesgo a ecosistemas es la identificación de puntos finales adecuados que son indicadores de la salud del ecosistema y sensitivos a las primeras etapas

del cambio antropogénico. Para relacionarse con la sociedad humana estos puntos finales deben ser asociados con consecuencias sociales, económicas y/o culturales. Por ejemplo, el desarrollo descontrolado de la minería puede afectar la calidad de las aguas lo que ocasionará la pérdida de la pesca comercial. El uso excesivo de ciertos tipos de pesticidas puede causar la extinción de megafauna carismática con distinción nacional. Desde una perspectiva operacional, los puntos finales pueden ser medidos fácilmente, cuantificados, y pueden ser sujetos al análisis estadístico. Deben ser sensitivos a las primeras etapas de amenazas ecológicas para permitir el uso de medidas paliativas.

Ejemplos de puntos finales incluyen estimaciones cuantitativas de la densidad de especies importantes y carismáticas de megafauna con gran valor comercial, la invasión o introducción de especies pestes a gran escala, cambios en la concentración de nutrientes críticos (tanto pérdidas como ganancias), sobre todo esos nutrientes como el nitrógeno y el fósforo que se sabe controlan la producción primaria, y medidas de la estructura de la comunidad como la densidad, riqueza de especies, diversidad, semejanza, y predominación.

Los puntos finales pueden ser arreglados de acuerdo a perfiles para caracterizar y monitorear a través del tiempo la salud ecológica del recurso y del ecosistema en cuestión. Investigación adicional para determinar los puntos finales ecológicos, las propiedades estadísticas, y la frecuencia con la que se obtienen las medidas es aún necesaria.

RESUMEN

El modelo que se presenta para el desarrollo y el uso de los inventarios de recursos se está aplicando a los recursos naturales acuáticos en Parques Nacionales en los Estados Unidos (Boyle el. al., 1991). Eugenio Odum (1975) ha caracterizado la ecología como el puente entre las ciencias sociales y las ciencias naturales. La forma en que los inventarios serán usados determina como los datos serán coleccionados. Cómo los inventarios son usados depende de los valores de la nación y la región, su situación económica, sus costumbres, sus prácticas, y sus leyes. Lo que es importante es la formulación de una estrategia que sea apropiada y la programación de colección de datos sobre recursos de inventarios que tenga aplicaciones ecológicas amplias para el manejo de los recursos y la protección del ecosistema.

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Análisis, Evaluación y Reporte: El Monitoreo Ecológico en la Laguna Ojo de Liebre

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RESUMEN.--En este trabajo se presentan algunos de los métodos utilizados para analizar los resultados de monitoreos, realizados por diferentes investigadores a través del tiempo, sobre dos especies (ballena gris y águila pescadora) y como estos monitoreos tienen una aplicación práctica, por ejemplo en estudios de impacto ambiental y para actualizar el estatus de las poblaciones.

INTRODUCCION

El medio ambiente ha venido a ocupar un lugar privilegiado en los foros en los que se analizan y plantean la orientación de las políticas económicas y comerciales que prevalecerán al finalizar el presente siglo. Actualmente existe un consenso entre las naciones con respecto a la importancia de lograr un desarrollo sostenido, que haga posible el crecimiento económico sin por ello poner en riesgo los recursos naturales que hemos heredado y que debemos preservar para las generaciones futuras.

Las evaluaciones ambientales, en principio, fueron adoptadas para asegurar un desarrollo sostenido, esto es, que el desarrollo no dañara irreversiblemente los procesos ecológicos esenciales. En la práctica ésto ha sido institucionalizado y típicamente aplicado, en México y muchos otros países, sólo en los proyectos de desarrollo que son individualmente grandes, suficientes para generar impactos evidentes. Otras actividades y prácticas de manejo, colectivamente numerosas, escapan a las evaluaciones. La aplicación esporádica de las evaluaciones ecológicas contribuyen a la erosión acumulativa de la integridad ecológica.

Por esto se requiere de un marco más integral de las evaluaciónes ambientales para identificar y encontrar las consecuencias de las pérdidas acumulativas y los cambios en las capacidades regionales de los ecosistemas naturales, modificados y degradados.

En nuestro país existen algunos problemas cuando se trata de hacer evaluaciones ambientales:

1. A veces se carece de la información técnica necesaria para evaluar apropiadamente un ecosistema. Actualmente los procesos de evaluación están limitados por la disponibilidad y/o la calidad de la información técnica sobre la cual se predicen la naturaleza y severidad de los impactos y sus consecuencias para la sociedad. Por ejemplo en el campo de la vida silvestre no existen suficientes líneas de base desarrolladas, estudios de monitoreo o estudios experimentales para generar relaciones causa-efecto significativas o correlaciones entre las acciones de desarrollo y las reacciones ecológicas. Esto es el resultado de la complejidad de los asuntos técnicos y los altos costos de llevar a cabo estudios científicamente adecuados.
2. El segundo problema con el que se enfrentan las evaluaciones y análisis ambientales es la objetividad. Objetividad para discriminar entre los elementos ambientales reales y los espurios y la politización de los asuntos biológicos dentro de los procesos de evaluación

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ambiental. Esta última existe en dos formas. La primera es el uso parcial de información científica para promover valores no científicos. Un ejemplo es la deliberada o inadvertida exageración de los efectos adversos de un proyecto sobre la vida silvestre, como serían las incursiones forestales dentro de un área desértica, cuando la verdadera razón es la preferencia estética de mantener prístina el área, sobre la del riesgo de tener una productividad sostenida. Una utilización manipulativa similar de los datos base, puede encontrarse en la promulgación de intereses de desarrollo creados. El segundo ejemplo de la politización negativa ocurre cuando los asesores técnicos están influenciados por la aceptabilidad de los políticos de diferentes opciones políticas y estructuran sus consejos de acuerdo a aquellas percepciones, más que de acuerdo a los criterios técnicos objetivos. De este modo los requerimientos analíticos del sistema se acaban. Estas tácticas han contribuído a la confusión, a la aceptación sin crítica de los rumores o habladurías en los procesos de evaluación ambiental, y a la toma de decisiones imperfectas. Esto es una de las mayores fuerzas de disuasión para el progreso en la definición de las cuestiones reales y para el enfoque de como resolverlas. Uno de los elementos que indudablemente pueden contribuir a enfocar objetivamente cualquier estudio ambiental es el de contar con sólidos estudios de monitoreo ecológico.

3. Y por último la carencia de coordinación de los distintos niveles; municipal, estatal y federal en la planeación ambiental. Los mecanismos regulatorios y de evaluación varían ampliamente a través del país. Por lo que es necesario una mayor vinculación entre las acciones de los diferentes niveles del gobierno para asegurar el mantenimiento de la calidad ambiental y sus valores. Igualmente, el contar con adecuados monitoreos ecológicos puede contribuir a que los tomadores de decisión pudieran dictaminar sobre bases objetivas.

En México, al igual que en otros países, existe la tendencia de enfocar los mega-proyectos como los poseedores de mayores implicaciones ambientales mientras que acciones comparables realizadas en áreas de asentamientos reciben poca o ninguna atención. Es irónico que muchas personas quienes exprésan su preocupación ambiental por el desarrollo en áreas lejanas, no pueden reconocer la importancia de la pérdida de los hábitats y la degradación ambiental asociados a la expansión de la mancha urbana y el desarrollo en su área local.

Para una adecuada evaluación y análisis de los recursos o ecosistemas se requiere esencialmente de líneas de base y de monitoreos ecológicos directos para que los esfuerzos de evaluación sean efectivos. Sin embargo los monitoreos o biomonitoreos en el pasado eran muy específicos. Se limitaban a pruebas de toxicidad o estudios sobre especies indicadoras. Las evaluaciones que utilizan los "guilds" aplican los principios ecológicos de un modo más integrativo. Las mejores aplicaciones a largo plazo son el desarrollo de juegos métricos, como aquellos utilizados en los índices de integridad bióticos (IBI) , que reflejan los atributos individuales, poblacionales, de la comunidad y del ecosistema en un marco integrativo.

A continuación se presnta un caso de estudio como ejemplo.

PROYECTO: SALITRALES DE SAN IGNACIO

En el mundo se producen 200 millones de toneladas anuales de sal, mineral no metálico imprescindible para las industrias química, alimenticia, manufacturera, textil, farmaceútica y agrícola, entre otras.

De esa cifra global, 10 por ciento es materia de comercio internacional y es obtenida mediante la evaporación de agua de mar, proceso de producción que requiere una serie de características excepcionalemente localizables en un sólo punto geográfico: suelo plano, impermeable, con un contenido específico de sal, con precipitación pluvial mínima y mucho viento.

De ese 10 por ciento que se comercializa internacionalmente (alrededor de 20 millones de toneladas métricas de sal común o cloruro de sodio), México se encuentra en segundo lugar, como puede observarse en la siguiente tabla:

TABLA No.1

País	Millones de T. M. de sal
Australia	6.5
México	6.0
Holanda	2.2
Alemania	1.6
Canadá	1.5
Bahamas	1.2
Chile	0.6
Francia	0.4

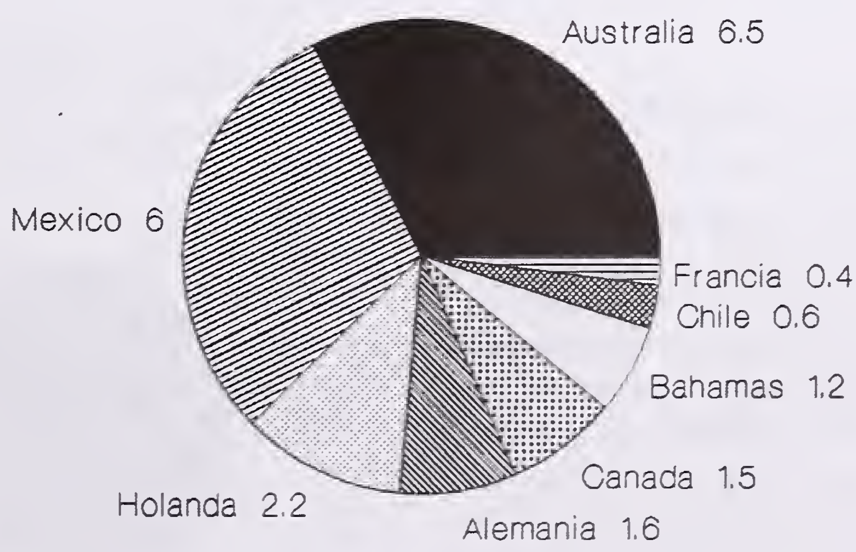
En el estado de Baja California Sur, se encuentran algunos de los escasos sitios del mundo que reúnen esas condiciones físico-climatológicas. Desde hace cuarenta años, la Compañía Exportadora de Sal, S.A. de C.V. (ESSA) produce sal por evaporación solar en Ojo de Liebre y Guerrero Negro. ESSA, empresa mexicana con participación estatal mayoritaria y coinversión en 49 por ciento con la corporación privada Mitsubishi, en 1994, presentó un proyecto, de ampliación de sus intalaciones, para la construcción de una nueva planta salinera en las proximidades de la laguna San Ignacio.

Con la creación de la nueva salina en el área de la Laguna San Ignacio, se duplicaría la producción a 12 millones de toneladas anuales, lo que colocaría a México como el productor de sal más importante del mundo, por encima de Australia que es su más cercano competidor.

Por otro lado, durante miles de años la ballena gris, se traslada anualmente durante el invierno, desde los fríos mares de Chukchi, Behring y Beaufort, con el fin de aparearse y alumbrar, a las cálidas aguas de cuatro lagunas costeras mexicanas; Laguna Ojo de Liebre, Laguna Guerrero Negro, Laguna San Ignacio y el complejo lagunar de Bahía Magdalena, en Baja California Sur. Las leyes mexicanas han decretado protección total a la especie y a su hábitat mediante decretos específicos y declarando como Reserva de la Biosfera a la región del Vizcaíno- Ojo de Liebre. Por varias décadas, ESSA ha coexistido en armonía con las ballenas y otras especies en la zona de amortiguamiento de la Reserva.

Como parte del Estudio de Impacto Ambiental para determinar si la construcción de un muelle que contempla el proyecto¨ Salitrales de San Ignacio¨ y los movimientos marítimos que resulten de su operación, se analizaron los datos obtenidos por varios investigadores a traves de los años, sobre las poblaciones de ballena gris y de águila pescadora en el

Paises productores de sal



complejo lagunar Ojo de Liebre-Guerrero Negro, con el fin de que obtener una evaluación sobre el monitoreo de estas especies, y así poder analizar los factores que han influido en el estatus en el que se encuentran dichas poblaciones, incluyendo las actividades de ESSA.

Ballena gris (*Eschrichtius robustus*)

Esta especie es la única representante de la familia Eschrichtidae. La población casi desapareció a principios del siglo, y logró recuperarse en gran parte por la protección del gobierno mexicano. A principios de la década de los 1970´s la población total se estimó en 10,000 individuos (Rice y Wolman, 1971; Maravilla, 1991); mientras que a principios de los 1980's se hablaba de 16,000 (Reilly et al, 1983; Aurioles-Gamboa, 1993). A pesar de esto, aún se le menciona en la categoría de especie amenazada (Braham, 1984; Aurioles-Gamboa, 1993). La abundancia poblacional en el extremo sur de su distribución se ha mantenido constante durante los últimos 15 años (Fleisher, 1990).

Objetivos

En este caso la recopilación de los datos tuvo como propósito el brindar elementos de juicio que, en la medida de lo posible permitieran evaluar si las actividades de contrucción operación y mantenimiento del proyecto "Salitrales de San Ignacio" serían suceptibles de generar impactos sobre la población de ballena gris; que pudieran modificar su comportamiento, alterar su ruta migratoria o afectar en cualquier forma el desarrollo de esta especie en la zona.

Para el efecto se procedió a desarrollar las siguientes actividades:

1. Análisis de la información bibliográfica disponible a nivel internacional.

Se abordó un análisis preeliminar de la información publicada en los últimos años en revistas científicas de reconocido prestigio internacional, a fin de definir las fuentes de impacto más frecuentemente asociadas con las modificaciones en la conducta, abundancia y reproducción de ballenas en general. Para el efecto se revisaron los resúmenes de publicaciónes científicas sobre ballenas, obtenidos mediante la consulta de los siguientes bancos de datos:

- Aquatic Science and Fisheries Abstract.
  Período 1978- 1995
- Life Science Collection.
  Período 1982- 1995
- Biological Abstrac.
  Período 1991-1995
- Current Contents.
  Período 1994-1995

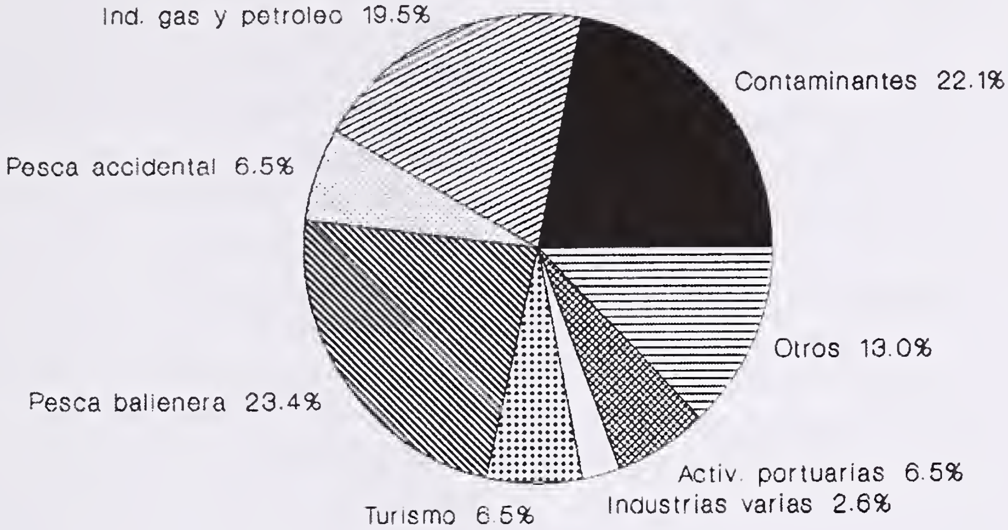
Los resultados del análisis bibliográfico (Tabla No. 2), permiten evidenciar que las actividades portuarias rara vez son mencionadas en la literatura centífica como fuentes de impactos sobre poblaciones de ballenas. Y en síntesis, estas actividades, en general no parecen ser consideradas una fuente significativa de impactos sobre poblaciones de ballenas, si bien se mencionan comportamientos elusivos asociados a la generación de ruidos en áreas localizadas y con fuerte actividad marítima e industrial.

Tabla No. 23

Tabla No. 2	NUMERO DE REFERENCIAS	PORCENTAJE
BALLENAS	4474	
BALLENAS E IMPACTO	77	1.72
CONTAMINANTES	17	22.08
INDUSTRIA DE GAS Y PETROLEO	15	19.48
PESCA ACCIDENTAL	5	6.49
PESCA BELLENERA	18	23.38
TURISMO	5	6.49
INDUSTRIAS VARIAS	2	2.6
ACTIVIDADES PORTUARIAS	5	6.49
OTROS	10	12.99

Analisis bibiliografico
Numero de referencias

Referencias por tipo de impactos



2. Análisis de las fuentes potenciales de impactos.

Los impactos esperables durante la fase de contrucción del muelle, en términos de la población de ballena gris, son de carácter temporal (dado que esta etapa del proyecto también lo es) y restringido; puesto qu sólo afecta parte del área de distribución del recurso en la zona de la Laguna de San Ignacio.

Existen estudios previos que permiten afirmar que no es probable que la construcción y operación del muelle afecte en cualquier forma a una fracción considerable de la población. Los resultados de un estudio realizado en la zona por personal de la entonces subdelegación de Protección Ambiental (Ramírez y Velázquez, 1994), indican que la mayoría de las ballenas no frecuentaron la bahía durante sus movimientos migratorios (sólo 12 de 321 ballenas censadas transitaron a tres kilómetros o menos de distancia de la costa, lo que significa un 3.7%). Dado que únicamente entre un 20-30 % de la población de ballena gris ingresa a la laguna de San Ignacio (Maravilla, 1991), y que el resto no utiliza el área más costera durante su migración, puede estimarse que menos del 1 % de la población podría experimentar la influencia directa de la generalidad de las actividades de construcción y operación.

Las fuentes de impactos potenciales tanto durante la construcción como de la operación pueden clasificarse en tres tipos: generación de ruidos, perturbaciones por tránsito y alteraciones de las características fisicoquímicas del medio marino.

a) **Generación de ruido.** Tanto la naturaleza del fenómeno físico (la mayor parte del sonido es treflejado por la superficie del agua) como los estudios realizados para otras especies de ballenas (Richardson et al., 1991) indican que serían necesarios ruidos de gran intensidad para producir perturbaciones en el comportamiento de la ballena gris en la zona. Y aun se podría evitar cualquier perturbación efectuando las actividades generadoras de las mayores intensidades de sonido fuera de los meses en los que la ballena gris utiliza la zona en su migración.

Por otro lado no se ha demostrado que el ruido generado por embarcaciones constituya una fuente de impactos de mayor consideración y aún en el caso de tráfico pesado e intenso como por ejemplo en la Bahía de Tokio se desconoce su efecto real en las poblaciones de ballenas aunque en este caso ha sido señalado como posible causa de la disminución de la ballena *Balaenoptera acotorostrata* en el área (Nishiwaki, 1977).

b) **Perturbaciones por tránsito.** Dada la naturaleza del proyecto, la ausencia e de cantidades significativas de ballenas en dicha zona hace que los impactos derivados sean inexistentes. A la luz de los resultados del estudio de tránsito de ballenas en la zona (Ramírez y Velázquez,1994), puede afirmarse que el único tránsito que pudiera constituir una perturbación es el de las embarcaciones que apoyarán las labores de construcción. Dado que dicho tránsito ocurrirá en los primeros dos a tres kilómetros de la costa, es esperable que la población de ballena gris sólo esté sujeta a su influencia de forma muy marginal. Además, hay evidencias de que el sólo tránsito de embarcaciones no ha tenido efectos adversos sobre las poblaciones de ballena gris en otras lagunas costeras de la región (Swartz y Jones, 1994: Fleisher y Beddington, 1985: Maravilla, 1991).

c) **Modificaciones de las características fisicoquímicas del medio marino**. Los impactos atribuibles a modificaciones de las características fisicoquímicas del medio marino, tienen su origen principalente en los procesos de bioacumulación. Lo cual respecto al proyecto que se analiza, las mayores modificaciones del medio marino podrían provenir de la resusupensión de sedimentos durante el piloteo, y de los combustibles, lubricantes y pinturas . Ambos tipos de contaminación , en el caso de que así fuese, se generaerían en cantidades despreciables. Aunado a esto existen dos factores adicionales que permiten afirmar que el impacto sería despreciable; uno son las corrientes prevalecientes en la zona y el segundo es que las ballenas no se alimentan durante su estancia en la zona (Maravilla, 1991), eliminando con ello las posibilidades de bioacumulación de contaminantes.

3.- Identificación de impactos potenciales mediante analogía con otro caso de estudio.

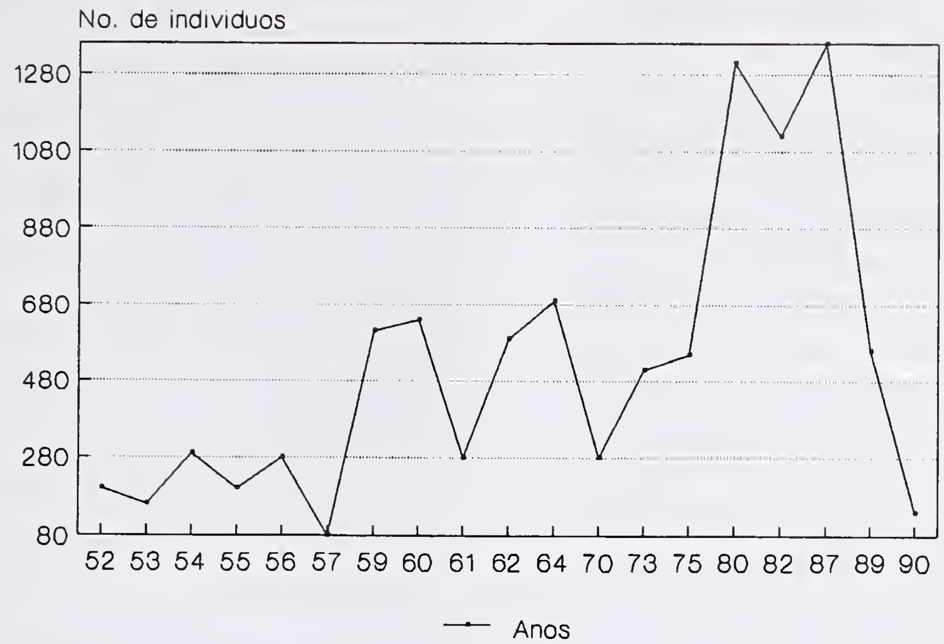
El caso que se analiza cuenta con un proyecto similar en escala 1:1, operando en la misma forma desde 1967: la salina de laguna Ojo de Liebre. Dicha salina presenta características de operatividad equivalentes a las de la que se planea implementar. En el caso particular de las ballenas, incluso presenta condiciones que implicarían mayores riesgos de impacto, ya que el transporte de sal conlleva el tránsito constante de barcazas y remolcadores, dentro de la zona de refugio, a diferencia del proyecto de Salitrales de San Ignacio en donde la sal se cargaría directamente en los buques cargueros. Finalmente se cuenta con información histórica respecto a la producción de sal y el número promedio de barcazas por año, y de la cantidad de ballenas presentes en laguna Ojo de Liebre. Ello permitió establecer si existe o no correlación estádistica entre la abundancia del recurso en la zona de actividades y la intensidad de la misma.

En la tabla No. 3 y en la figura No. 1 se muestra la serie de abundancia de ballenas en la laguna Ojo de Liebre para el período de de 1952 a 1994. Puede observarse que el recurso, además de su tendencia al incremento, presenta una gran varibilidad interanual que, podría suponerse, obedece tanto a variaciones ambientales como a diferentes intensidades de la actividad salinera.

Tabla No. 3

Año	No. de Individuos
1952	193
1954	286
1956	279
1960	634
1970	475
1980	1301
1988	537
1990	134

Abundancia de Ballena gris
en laguna Ojo de Liebre



A fin de identificar si tal variabilidad está influída por la actividad salinera, se procedió a correlacionar tanto el número promedio de viajes/barcazas como los volúmenes de producción anual, contra el número de ballenas presentes en la laguna. Los diagramas de dispersión se presentan en la Figura No. 2. Como puede observarse, no existe una relación estadísticamente significativa entre la actvidad industrial y la abundancia de ballenas en la localidad; lo que significa que, de existir algún impacto sobre el recurso éste no puede considerarse significativo sino que es enmascarado y diluído por la variabilidad natural. En especial para el caso de la ballena gris, se ha mencionado que la variación de algunos parámetros ambientales, como salinidad y temperatura, puede explicar cambios en el número de ballenas en el área de Ojo de Liebre como consecuencia de migraciones hacia otras lagunas costeras de la región (Maravilla, 1991). Y por último, en el complejo lagunar Ojo de Liebre-Guerrero Negro no se reportan efectos nocivos en la población de ballena por la presencia humana (Swarts y Jones,1984; Fleisher y Beddington, 1985).

CONCLUSIONES

No es probable que la construcción y operación de la obra proyectada pudieran modificar el comportamiento (incluyendo la ruta migratoria) de la ballena gris de forma significativa (esto es, de forma que fuese evidente por encima de los cambios interanuales generados por la variabilidad ambiental natural). No obstante, existe la posibildad de que se presenten comportamientos elusivos en las inmediaciones de la obra en cuestión, atribuibles básicamente a la generación de ruidos, lo cual puede ser evitado con una calendarización adecuada tanto de las actividades de construcción como las de operación.

Aguila Pescadora (*Pandion haliaetus carolinensis*)

El Aguila Pescadora, es una especie de amplia distribución en el mundo (Bent 1937, Prevost 1983). Como consecuencia de la declinación numérica de las poblaciones de águila pescadora en el noreste de los Estados Unidos de Norteamérica (Ames y Mersereau 1964), un gran número de estudios se emprendieron sobre esta especie. Las investigaciones documentaron disminución numérica, baja productividad, contaminación por desechos ambientales y adelgazamiento de cascarones en regiones de Norteamérica, principalmente en la costa Atlántica, con la implicación en estos fenómenos de pesticidas y otros contaminantes (Ames y Mersereau 1964, Henny y Wight 1969, Henny y Ogden 1970, Henny 1975, Henny y Noltemeir 1975, Anderson y Hickey 1972, Wiemeyer *et al.* 1975, Spitzer *et al.* 1977). Asimismo, distintas regiones de Norteamérica se exploraron para determinar la distribución, abundancia y

productividad del águila pescadora (Henny y Wight 1969, Henny y Van Velzen 1972, Henny *et al.* 1974, Henny y Anderson 1979, Postupalsky 1977, Jehl 1977). Otros aspectos estudiados fueron su biología reproductiva y energética (Ames 1964,), eficiencia de forrajeo (Grub 1977, Judge 1983).

La población de águila pescadora del complejo lagunar Ojo de Liebre-Guerrero Negro, es decir del área de estudio del presente trabajo, ha estado creciendo desde 1947 (Castellanos 1983), a diferencia de la mayoría de las poblaciones de los E. U. A., que durante ese período enfrentaron severas declinaciones. Las evidencias sugieren que la presencia del DDT y otros contaminantes en los huevos de águila pescadora de la región, incluidos los de Ojo de Liebre, fue relativamente menor que en otros sitios de Norteamérica, y el efecto sobre el espesor de los cascarones no significativo biológicamente.

En el complejo lagunar Ojo de Liebre-Guerrero Negro, históricamente las parejas de águila anidaban en sitios naturales en los islotes (Kenyon, 1947 y Jehl 1977). Sin embargo a partir de 1953 la zona, hasta entonces en condiciones pristinas, comenzó a ser poblada (J. C. Peralta, com. pers.). Como consecuencia de las modificaciones del habitat derivadas de las actividades humanas productivas y de programas de manejo de fauna gubernamentales (consistente entre otras acciones en la oferta de sitios de anidamiento artificiales) intrumentados a partir de 1980, algunos cambios se han registrado en la población de águila pescadora del complejo lagunar.

Evidencias de estudios previos sugieren que en el área de estudio, los factores que mayormente afectan el crecimiento poblacional del águila pescadora son: (1) la escasa disponibilidad de sitios naturales de anidamiento atractivos, (2) la depredación de huevos y pollos (por coyotes y gaviotas) y (3) la destrucción de nidos por altas mareas y vientos (Henny y Anderson 1979, Castellanos 1983). Aparentemente los cambios en el tamaño y distribución de la población reproductora de águila pescadora dentro del área de estudio y en el éxito reproductivo de las parejas, están asociados a su vez a los cambios, durante los últimos años, en esos factores en los islotes y a la mayor oferta de sitios de anidamiento artificiales atractivos fuera y dentro de las islas.

OBJETIVOS

A. Determinar el estatus actual de la poblacion reproductora del complejo lagunar ojo de liebre-guerrero negro, en terminos de distribucion y abundancia
B. Describir la cronologia reproductiva y determinar los parametros demograficos de la poblacion en el ciclo reproductor 1992-1993, especialmente el exito reproductivo
C. Identificar y evaluar los factores que afectan el crecimiento de la poblacion
D. Describir y determinar los requerimientos de anidamiento y evaluar el impacto de las actividades humanas y de manejo (oferta de sitios de anidamiento) en la distribucion, abundancia y exito reproductivo de la poblacion

AREA DE TRABAJO

El trabajo se desarrolló en el complejo lagunar Ojo de Liebre-Guerrero Negro e imediaciones en conjunto abarcando una superficie de aproximadamente 500 Km². Este complejo lagunar se localiza en la porción media occidental de la península de Baja California, abierto a la gran bahía de Sebastián Vizcaíno (27º37'-28º05'N, 113º55'-114º19'W). La laguna Guerrero Negro es la de posición más norteña, de forma rectangular y de cerca de 110 Km². La Laguna Ojo de Liebre, de mayor extensión (360 km²), está separada de la laguna Guerrero Negro por un pequeño brazo de tierra, no muy ancho, que es cubierto por el agua durante las altas mareas.

Ambas lagunas son poco profundas (6-12 m), con canales y corrientes de velocidad considerable, de cuatro a cinco nudos. La márgenes de las lagunas están constituídos por dunas no estabilizadas, ciénegas salobres, planos salitrosos y vasos de evaporación construidos para la producción de sal. Alrededor de las lagunas se encuentran grandes planicies del Desierto de Vizcaíno, cubiertas de matorral de tipo halófilo, de escasos 30-50 cm de altura. La región se caracteriza por temperaturas moderadas, un alto porcentaje de días nublados y fuertes vientos. Es notorio en esta zona la ausencia de árboles, riscos y de otras elevaciones naturales.

Dentro de la laguna Ojo de Liebre se encuentran cinco islotes: Conchas, Zacatoza, Piedras, Brozas y La Choya. Asimismo se hallan dispersas en las lagunas numerosas torres artificiales utilizadas para señalar los canales, fondos bajos y margenes de las lagunas a los navegantes. Estas lagunas han sido consideradas una de las más bellas, naturales y productivas áreas en el mundo (Bostic 1975), ofreciendo hábitats favorables para un gran número de aves acuáticas invernantes, residentes, playeras y marinas. Cerca de ambas lagunas hay un pequeño pueblo, Guerrero Negro, con 6,000 habitantes, establecido a inicios de los años 1950's. Descripciones más extensas de las características de las lagunas se pueden encontrar en Bostic (1975); Saunders y Saunders (1981) y Contreras (1988).

Tabla No. 4

Año	No. de parejas
1946	27
1971	30
1977	50
1980	71
1981	76
1982	86
1993	126

CONCLUSIONES FINALES

Las razones para instituir un programa de monitoreo pueden clasificarse en tres grandes categorías:

1.- Para evaluar la efectividad de una política o legislación;
2.-Como una función regulatoria o de auditoría;
3.- para detectar cambios incipientes

Y estas categorías no son excluyentes mutuamente

1. Monitoreo de la efectividad de una política o legislación

La legislación comunmente intenta asegurar el matenimiento de una condición deseable o facilitar el progreso hacia esa condición. Un ejemplo de esta categoría sería la revisión cada determinado numero de años (por decir, cada cinco), de las especies protegidas y enlistadas como raras o en peligro de extinción. Es necesario el monitoreo del estatus de la población, para poder actualizar dichas listas.

2.- Como una función regulatoria o de auditoría

La mayoría de los monitoreos realizados día a día para propósitos de manejo se incluyen en esta categoría. Las regulaciones oficiales para la contaminación deberían ser rutinariamente revisadas para comparar los resultados de la recopilación de monitoreos con los estándares de calidad de los efluentes de agua, emisión de contaminantes a la atmósfera, ruido, etc. Y lo mismo sería recomendable en áreas "sanas" y seguras, por ejemplo monitoreos de la higiene en la preparación de alimentos, en la atención y cuidados médicos y en otras áreas de las actividades humanas.

3.- En la detección de cambios incipientes

Este último punto es el enlace de las tres categorias, el uso del monitoreo para dectectar cambios incipientes y usualmente indeseables. En los ecosistemas exiten tres grandes tipos de cambios intrínsecos: estocásticos, sucesionales y cíclicos. Los cambios estocásticos son, por definición impredecibles y por lo tanto no pueden ser anticipados por los esquemas de monitoreo. Estos cambios pueden estar asociados a cambios climáticos severos, tales como inundaciones, sequías, incendios y epidemias de enfermedades o parásitos. Los cambios sucesionales son un proceso ecológico normal el cual resulta de un ambio gradual de las comunidades y en la desaparición de las especies. Los cambios cíclicos pueden ser dramáticos en sus efectos, pero contribuyen a la persistencia indefinida de una población. Por ejemplo las interacciones predador-presa y dependencia-densidad.

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SUBJECT VI: RESEARCH AND DEVELOPMENT NEEDS

Presentations and Panel discussions focused on domestic and international science aspects of long-term monitoring for assessment activities. Issue areas for presentation and consideration included: the nature of gaps in scientific and technological knowledge inhibiting further improvement of monitoring approaches; capabilities and feasibility of integrating system complexity into monitoring efforts. Particular attention was given to issues of spatial, temporal and decision-level scale in advancement of the practice of ecological risk assessments and the investigation of comparative risk (that is, comparison of ecological and human health risks, and their management). Four resource groups were organized to address this subject: (1) Forest and Range Lands, (2) Surface Waters and Wetlands, (3) Estuaries and Coastal Waters, and (4) Agroecosystems.

Forest Sustainability and Forest Health: A Canadian Approach

J. Peter Hall[1]

Abstract. - Canada is committed to the sustainable management of our forests. The CFS in cooperation with other forest stakeholders is developing a set of Criteria and Indicators to assess the progress toward this goal. On important element of this process is that of forest health. The state of health of forests must be known if actions are to be taken to preserve forest health or to act to restore forest health if this is endangered.

The CFS has developed forest health monitoring networks to address the issues of forest health. The Acid Rain National Early Warning System (ARNEWS) and the North American Maple Project (NAMP) have been in operation for several years and are the best known. These monitoring systems evaluate the condition of tree crowns, determine what stress factors are affecting trees and from this information assess the state of health of forests.

The monitoring systems have shown that the greatest proportion of stresses on forests are those of insects, diseases, and weather extremes; all natural features of the environment. The monitoring systems have identified known cases of air pollution damage on forests and other instances of possible air pollution damage. Systems to monitor the health of forests are an integral and essential part of sustainable forest management.

INTRODUCTION

Canada is in the process of developing an approach to sustainable forest management. The CFS as the research arm of the Government of Canada is playing a leading role in this initiative. We are cooperating with the provincial governments who are responsible for forest management, and industrial partners who manage the forest for economic goals. Two broad initiatives are being followed.

Firstly, we are developing a set of Criteria and Indicators the goal of which is to demonstrate to our citizens and to the world generally that our forests are being managed in an ecologically and sustainable sound manner. These are aimed at characterizing sustainable forest management, providing the basis for domestic policies on sustainability, and developing concepts that facilitate the ongoing dialogue on sustainable forest management. There are 86 Indicators used to assess the six Criteria and forest health activities contribute to several of these.

Secondly we have initiated the Model Forest Program, 10 domestic and three international, in Russia, Malaysia and Mexico. These are designed to demonstrate and test various aspects of forest sustainability and to bring together forest dwellers, forest users, and forest managers to manage these forests.

It is axiomatic that the state of health of forests must be understood if actions are to be taken to preserve forest health or to act to restore forest health if this is endangered. The CFS has over the past decade developed systems to monitor forest health to respond to the needs of forest managers and policymakers. These forest health monitoring systems are evolving from previous surveys including the well-known Forest Insect and Disease Survey which has been operating for 60 years. This paper

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describes two of these monitoring systems; the Acid Rain National Early Warning System (ARNEWS) and the North American Maple Project (NAMP). For the purposes of this paper, forest health is defined as the conditions of forest ecosystems that sustain their complexity and vitality.

METHODS OF ASSESSING FOREST HEALTH

The issue of forest health is particularly important today with the greater awareness and interest of the public in the values of the forest as a multiple-use resource. Perceived stressors like climate change, air pollutants and the human impact on forests pose questions about current and future forest sustainability. We also need to be aware of the influences in the forest of growth-impacting stressors, and to be able to explain changes in tree condition. Forest health monitoring networks provide the knowledge base to address these issues.

Monitoring biological responses to stresses in the field is difficult because biological systems respond to a complex of environmental factors rather than to a single factor such as 'air pollution' (Bormann 1985). Other stresses affect forests, with such large impacts that subtle responses such as pollution are lost in the 'noise' of the data. Moreover, by the time that pollution-caused damage is evident extensive damage may have already occurred. It must be realized that trees are only one part of the forest and only a few parameters are measured on trees, so in a sense only a part of the forest is being assessed.

Trees are altered by stress and then become increasingly susceptible to insect and disease organisms that attack and may kill them (Manion 1981). Forest ecosystems are not usually permanently damaged by periodic stress and recover to a state resembling their original condition. It is usually the interaction of several abiotic and biotic factors that produces an unhealthy forest rather than the effect of a single factor (Hall and Addison 1991). The CFS assesses the state of the health of the forest using a common set of measurements taken on permanent sample plots (Hall and Addison 1991). In 1984, the CFS the ARNEWS network to assess the state of health of forests based on tree mortality, crown condition and presence of pollution damage. The ARNEWS network detects early signs of the effects of acid rain on forests so that action can be taken to forestall anticipated damage. The strategy of ARNEWS is to isolate damage attributable to natural causes or management practices, and to monitor the long-term changes in vegetation and soils attributable to acid deposition and other pollutants. The symptoms of air pollution damage are not highly specific, and they frequently resemble damage from other causes. The experience of field technicians trained to distinguish these symptoms from abnormal climatic conditions, nutrient deficiencies, and the effects of insects and diseases is crucial to the functioning of ARNEWS. Data collected in the ARNEWS are supplemented by the results of other CFS surveys and its cooperating agencies.

In addition, to the ARNEWS, the CFS operates jointly with the USFS, a monitoring system for sugar maple. Sugar maple is one of the most important hardwood species in eastern Canada and concerns about its health were widespread during the 1980's. It was widely proposed that airborne pollutants were damaging the trees (Millers et al 1989). In 1988, the U.S.D.A. Forest Service and the CFS established a network of monitoring sites in the northeastern United States and Canada over the range of sugar maple (Millers et al. 1991).

In order to evaluate forest health, assessments for both networks are based on (a) Mortality levels: are they normal or greater than normal? (b) Dieback/ defoliation: is it enough to affect tree health? (c) Symptoms of pollution damage: are there any present?

(a) Mortality

The CFS uses the range of 1-2% as normal annual mortality in unmanaged forests, resulting from natural thinning as the stands age. Mortality in excess of this rate could be caused by any number of natural factors, insects, diseases, windthrow, drought; or by anthropogenic factors such as air pollution. The cause of tree mortality is determined in the field, supplemented by laboratory examination if necessary.

(b) Crown Condition

The condition of tree crowns is used to evaluate forest health. The classification system for hardwoods is based upon the visible parts of the outer crown; the quantity and quality of foliage in the outer crown, the percentage of the outer crown that contains bare twigs, and dead branches. Larches/Tamaracks are assessed as if they were hardwoods (D'Eon et al 1994).

Crown condition is assessed by dieback, and transparency (Table 1). There is a direct link between the amount of crown defoliation or dieback and the health of the tree. Trees are considered healthy if they are in the first three classes. As crown defoliation approaches 40%, the health of the tree begins to decline and it becomes susceptible to damage by secondary organisms. If crown dieback at a level of 50% persists for 2-3 years then there is an 80% chance that the tree will die within five years. Recovery is possible but as defoliation and/or dieback increases and persists, the possibility of recovery decreases (Lachance et al 1995).

Another measure of crown condition is that of transparency which is assessed in the NAMP network (Millers et al). Transparency is defined as the amount of skylight visible through the foliated portion of the crown and thus is the opposite of foliage density. The estimate is averaged for the living crown as a whole and estimated as a proportion of the crown that shows this condition. It is recorded in 10% classes, with 0% and 1-5% classes included. Trees in the first three classes, from 0-15% dieback, are considered to be in good condition (Millers et al 1991).

Table 1. Damage classes for crown condition in conifers, hardwoods and sugar maple in the ARNEWS and NAMP systems.

Conifer - Crown condition ARNEWS

1 - No defoliation.
2 - Only current foliage defoliated, total defoliation <25%
3 - Current and/or some older foliage defoliated, total <25%
4 - 25-50% total defoliation.
5 - 51-75% total defoliation.
6 - 76-90% total defoliation
7 - More than 90% total defoliation.
8 - Tree died since last assessment.
9 - Dead tree.

Hardwood - Crown Condition ARNEWS

10 - Full complement of foliage, no visible crown damage.
20 - Foliage thin, off colour, no dead branches or bare twigs.
30 - No dead branches, bare twigs in <5% of the crown.
35 - No dead branches, bare twigs in >6% of the crown.
40 - Dead branches and bare twigs in up to 15% of the crown.
45 - Dead branches and bare twigs in 16-25% of the crown.
50 - Dead branches and bare twigs in 26-37% of the crown.
55 - Dead branches and bare twigs in 38-50% of the crown.
60 - Dead branches and bare twigs in 51-75% of the crown.
65 - Dead branches and bare twigs in 76% or more of the crown.
70 - More than 50% of the crown dead, only small adventitious branches present, usually at the base of the crown or stem.
08 - Tree died since last assessment.
09 - Dead Tree.

Transparency - NAMP

0 - 10% None to Light
20 - 40% Moderate to heavy
50 - 70% Heavy
70 - 99% Severe
- estimated in 10% classes

Crown transparency up to 25% is frequently observed and reflects the presence of drought, weather conditions at time of flushing, or insect defoliation significantly. Generally good growth the following year will bring back thick foliation (Lachance et al 1995). However, if a stand as a whole is above 25% transparency this may indicate significant stress with the possibility of dieback appearing the following year.

Conifers (except Larches) are classified according to the amount of crown defoliation (D'Eon et al 1994). Defoliation is defined as foliage missing for whatever reason from the normal foliage complement. Bare and dead tops are considered as defoliated. This takes into account the natural loss of needles as a twig matures. For example, defoliation of balsam fir by spruce budworm in the 30-40% range results in growth decline and an increased susceptibility to damage from other factors. Successive years of defoliation at these levels can result in tree death.

Insects and diseases are identified and their levels of damage are determined. Observations are made to coincide with the life stages of the different groups of damaging organisms.

(c) Air Pollution

Air pollution is the third measure of forest health. Many symptoms of air pollution damage are known; descriptions of these have been developed from laboratory fumigations or from field observations near point sources (Malhotra and Blauel, 1980). Nevertheless, symptoms of air pollution damage are not highly specific and often resemble damage from other causes. Air pollution has subtle effects on tree physiology, and the symptoms may be masked by the effects of natural conditions. Symptoms are recorded by field technicians trained to distinguish them from the effects of abnormal climatic conditions, nutrient deficiencies, insects, and diseases (Hall and Addison 1991). Damage from air pollution may indicate poor health since trees are not naturally adapted to stress from pollutants.

PROGRAM OBJECTIVES

The objectives of the ARNEWS program are to detect the possible damage to trees and soils caused by acid rain by identifying damage that is not attribut-

able to natural causes or management practices, and to monitor vegetation and soils to detect changes attributable to air pollutants.

The objectives of the NAMP program are to determine the rate of annual change in sugar maple condition; and to determine if the rate of change in tree condition differs between levels of sulfate and nitrate wet deposition, sugarbush and undisturbed forest, and various levels of initial stand decline conditions. Results from the monitoring are used to determine the possible causes of forest decline.

DATA RELIABILITY

Ocular estimation techniques for data collection are often considered to be somewhat unreliable because of observer bias and interpretation error (Burkman et al 1990). Monitoring systems assess tree condition over large areas across Canada's forested Ecozones (ARNEWS) or throughout a species range (NAMP). A common methodology is used but the program is carried out by several regionally based teams operating independently. The problems that can exist between observers and between regions raises concerns as to the consistency and reliability of tree condition data. The quality control (QC) program reviews the quality and reproducibility of data obtained from in the field. The objectives of the program are to carry out a national training program, do annual cross checks of critical variables, and to conduct tests of accuracy and reproducibility of methods.

Cross-check visits are made on plots within two weeks of the visit by the regular field crew. Crown condition and crown damage are assessed during the cross check and compared against the observations of the regular field crews. This ensures reproducibility of the data enabling reliable conclusions to be drawn.

RESULTS AND DISCUSSION

Results are summarized from the monitoring systems based on the data collected to date (Hall 1995a, 1995b, Cooke et al 1995). Data from the networks are not enough in themselves to provide a reliable assessment of the state of health of Canada's forests. The system and the analysis are supported by a variety of other surveys, the intensity varying from region to region but with the same end in mind, to assess the health of forests. Assessments are based on mortality rates, crown condition and pollution symptoms.

(a) Mortality

In the ARNEWS system between 1986-1993, the overall mortality was 1.11% with conifers having 1.03% and hardwoods 1.42% mortality (Table 2). These rates are within the normal range in maturing natural forests. Mortality varied among years because the amount of insect damage and drought conditions varied widely.

Most major species assessed had mortality rates of less than 2% annually (Table 3). Sugar maple in the NAMP system had an annual mortality rate of 0.9% between 1988 and 1994; the same as observed in the ARNEWS (Cooke et al 1995)(Table 2). However, three species had mortality rates at the high end of the scale, balsam fir (1.8%), trembling aspen (2.3%), and birch including white birch and northern paper birch 3.0%. The higher rates of mortality in balsam fir and trembling aspen resulted from damage caused by the east-

Table 2. Percentage mortality in ARNEWS plots 1986-1993

Year	All trees	All Conifers	All Hardwoods	White Spruce	Sugar Maple
1986	1.44	1.53	1.08	0.69	0.67
1987	0.96	0.87	1.35	0.32	0.67
1988	0.75	0.72	0.86	0.00	0.70
1989	0.83	0.69	1.38	0.23	2.42
1990	1.20	1.18	1.27	1.35	0.72
1991	1.60	1.42	2.36	0.69	1.41
1992	1.26	0.98	2.51	0.23	0.00
1993	0.84	0.84	1.54	1.04	0.60
Average	1.11	1.03	1.42	0.57	0.90

Table 3. Mortality rates and ingrowth for selected species in ARNEWS plots, 1987-1993

Species		Annual rate of mortality %
Eastern White Pine	*Pinus strobus L.*	0.8
Jack Pine	*P. banksiana Lamb.*	1.1
Lodgepole Pine	*P. contorta Dougl.*	0.8
Tamarack	*L. laricina (Do Roi) K. Koch.*	0.5
Black spruce	*Picea mariana (Mill.) B.S.P.*	0.9
White Spruce	*P. glauca (Moench) Voss*	0.6
Douglas-fir[1]	*Pseudotsuga menziesii (Mirb.)Franco*	0.9
Balsam Fir	*Abies balsamea (l.) Mill*	1.8
Trembling Aspen	*Populus tremuloides Michx.*	2.3
White birch[2]	*Betula papyrifera Marsh.*	3.0
Red Oak	*Quercus rubra L.*	0.9
Sugar Maple	*Acer saccharum Marsh.*	0.9

[1] *Includes Douglas-fir and Interior Douglas-fir.* P. menziesii. var. glauca (Beissn.) Franco

[2] *Mixture of White Birch and Mountain Paper birch* B. cordifoliaRegl.

ern spruce budworm (*Choristoneura fumiferana* Clem.) and the large aspen tortrix (*C. conflictana* Wlk.) respectively, and from subsequent damage caused by secondary insects and diseases which killed many trees. Trembling aspen was also subjected to a number of unseasonable early and late frosts which caused added stress to the trees.

White birch near the Bay of Fundy in eastern Canada was severely damaged by acid fogs that caused leaf browning and premature leaf senescence. This caused twig and branch dieback, and over several years many trees died and increased the mortality rate above normal (Magasi 1989). Birches in other parts of the species range had normal mortality rates. Apart from these species, mortality was in the normal range, and caused mostly by natural thinning as the stands aged. Mortality was caused by drought, frost, windstorms, winter storms, root rots, spruce budworm, and other defoliating insects (Hall 1995a).

(b) Crown Condition

Nearly all the observed damage on trees was caused by insects and diseases. Insects caused defoliation on most species throughout Canada, the greatest damage occurring on conifers in the Maritimes and Ontario.

Damage varied widely from year to year, among species, and regions. Occasionally damage was severe enough to cause mortality. Defoliating insects such as the eastern spruce budworm and the large aspen tortrix caused extensive defoliation in balsam fir and trembling aspen respectively. Jack pine was damaged by a disease (*Endocronartium harknessii* (J.P. Moore) Y. Hirat.) to the extent of causing occasional mortality. The damage though widespread in many instances forms part of the normal stresses in forests to which tree species are adapted. Recovery from stresses was also observed (Hall, 1995a, 1995b).

More than 90% of the sugar maple measured in the NAMP were considered healthy (Cooke et al 1995). Crown transparency as measured in the NAMP also varied widely among stands and over time. Transparency was usually higher in larger, older trees and in sugarbushes than in unmanaged stands. Transparency changed quickly in following stresses, in response to an infestation of an insect, pear thrips (*Taeneothrips inconsequenz* Uzel.) and in response to drought. In both cases transparency recovered in a year or two to normal levels. Thus transparency is not a good indicator of tree health (as is dieback) but is a variable that indicates rapid changes in tree condition (Lachance et al 1998).

Crown Condition and Deposition Levels

One of the objectives of NAMP is to evaluate the relationship between levels of dieback and transparency and wet deposition of pollutants. No consistent relationships were found between sulphate and nitrate deposition levels and dieback or transparency (Lachance et al 1995). However, for nitrate deposition, the data suggest a tendency of greater dieback at higher levels of deposition. Dieback was slightly higher at higher levels of deposition, but differences were statistically significant only in 2 out of the 6 years (1989, 1990), and only between low and high levels of nitrate deposition. The differences were probably not biologically significant, although the possible effects over time are unknown (Lachance et al 1995).

This increase in transparency may be caused by activities in sugarbushes causing more stress on the trees than in unmanaged stands. This additional stress may originate from soil compaction, tree wounding, frequent light thinnings, and tapping. It is probable that site characteristics have more impact on dieback and transparency levels than deposition. These include soil depth, soil fertility, buffering capacity, drainage, site exposure, insect defoliations, and drought or freezing. It must be realized also that deposition of pollutants varies in intensity and location from year to year so that individual plots may be in different deposition zones in different years. The results are similar to those reported by Allen et al 1992, which show no relationship between dieback and transparency and levels of pollutant deposition.

(c) Damage from pollution

White birch near the Bay of Fundy was severely damaged by acid fogs that caused leaf browning and premature leaf senescence. This caused twig and branch dieback, and over several years many trees died as a result. Leaf curl and marginal discoloration were also observed for a number of years (Magasi 1989). Signs of improvement were observed in 1989, and many trees have recovered since then. In 1991 healthy trees outnumbered those with branch dieback for the first time since 1985. The improvement in

tree condition is coincident with the decreasing frequency of acid fogs in the area (Cox et al 1989). In areas outside the Bay of Fundy, birches did not have these symptoms (Hall 1995a, 1995b).

In the Maritime Provinces, ozone-like symptoms have been observed on white spruce, black spruce, balsam fir, yellow birch (*Betula allaghiensis* Britt.), sugar maple, red maple (*Acer rubrum* L.), and white birch. These symptoms were small yellow flecks on the needles. Investigations continue to determine the cause. Apart from these instances, the ARNEWS network has not detected any pollution symptoms in Canadian forests.

ARNEWS PLOTS WITH DECLINE SYMPTOMS

Decline is defined as a continued and progressive deterioration of condition ending in the death of the tree (Manion 1981). Several plots in the ARNEWS had over 15% of the dominant and codominant trees with greater than 50% damage to their crowns for three or more years. These plots are also in areas of acid-sensitive soils and annual deposition levels in excess of 20 kg/ha, raising the question that pollutants may be adding stresses to trees already damaged. Pollution levels are low compared to most ARNEWS plots but the acidic soils means that they cannot buffer any incoming acidity. Damage on these plots was caused by defoliation by the eastern spruce budworm, other insects, diseases and abiotic factors. In some areas drought has added to the stresses. Recovery has been slower to occur than in areas of soils with higher buffering capacity. One of the plots was a coastal plot of birch damaged by acid fog. There is no direct evidence of pollution damage in the other plots, however, trees may be further stressed by the presence of pollutants in the higher deposition areas.

SOIL SAMPLING AND ANALYSIS

One of the objectives of the ARNEWS program is to monitor the effects of pollution on soil chemical properties at each ARNEWS plot. The initial sampling and analysis was made between 1985 and 1987 with additional samplings in 1990 and 1995. The results have shown that there are reductions in the concentrations of exchangeable base cations in relation to increasing deposition of sulfatea dn nitrate pollutants. This leaching has been observed in other soil solution chemistry studies in eastern North America. The data suggest that changes are taking place in the soils under the ARNEWS plots (Hall 1995a). The changes seem to be greatest in the zones of higher deposition suggesting that pollutants are causing changes in soil chemistry.

CONCLUSIONS

Results from ARNEWS and NAMP shows that mortality has generally been in the normal range for unmanaged forests with 1-2% of the trees dying annually from natural thinning. Where mortality levels were higher, the causes were readily determined to be from insects and/or diseases. The tree condition data indicate that the trees were generally healthy and their crowns were affected by a variety of insects, diseases and abiotic factors which normally damage forest trees. Thus most damage was explainable by the effects of insects, diseases and weather extremes. Forests are sensitive to environmental stress which varies with site which integrates the below ground properties with the above-ground conditions of climate and anthropogenic stresses.

There was a slight trend of higher transparency in sugar maple with increasing deposition of nitrates. The possibility of an impact from pollutants cannot therefore be eliminated, considering that other factors such as soil properties may synergize with deposited levels. Other stresses including, drought, insect defoliation, and soil properties had a more direct impact on crown condition. There were slightly higher levels of dieback in stands actively managed for sap compared to natural stands.

Investigations of symptoms concluded that the damage observed on birch in New Brunswick was caused by pollutants. Symptoms resembling those caused by air pollution damage were also observed in the Maritime Provinces and in British Columbia on birches, pines, Douglas-fir, maples and aspen. These symptoms also resemble those caused by insects, diseases or weather and investigations continue to determine the cause of the damage.

Constant monitoring is necessary to explain the causes of forest decline. It is necessary to monitor forest conditions to know what is happening, if we are to make conclusions on the state of the health of our forests.

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Research and Development Needs for Forest Ecosystem Monitoring

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Abstract.—Ecosystems span many levels of scale and complexity. A comprehensive forest ecosystem monitoring system will approach the problem from multiple perspectives and scales simultaneously. Some of the research and development needs are obvious, e.g. the need to develop indicators and models linking those indicators to stressors and resulting changes. Other important but less obvious research and development needs exist. Examples include (1) making better use of readily available auxiliary information which is not collected as part of the monitoring system; (2) development of information management, analysis, and reporting tools which can be used by a wide variety of people to examine potential ecosystem status and trend; (3) development of alternate paradigms for assessing environmental status and trend; and (4) reasonable and effective methods to assure the quality of monitoring data. Monitoring is not merely the implementation of research findings; monitoring itself is a type of applied research. The greatest present need for forest ecosystem monitoring is for the completion of an extensive forest ecosystem monitoring system to complement the existing set of intensive monitoring sites. Completion of the extensive monitoring system is vital if we are ever to become proactive in addressing public concerns about forested ecosystem status and change.

INTRODUCTION

Ecosystem monitoring and assessment is an exercise in applied research. There must exist a balance between the rigor of a statistically sound experimental design, and the flexibility to try new ideas usually associated with an exploratory research project. This paper outlines some of the research and development needs for a successful program based on my experience as a forester, as a scientist, and as manager of the Northern Forest Health Monitoring program (NOFHM) and of the Northeastern Forest Inventory and Analysis (NEFIA) program of the USDA Forest Service. The following pages will discuss briefly research needs, development needs, and the overriding need to tie research and development into a single cohesive program.

RESEARCH NEEDS FOR FOREST ECOSYSTEM MONITORING

There are many research needs to improve the state of forest ecosystem monitoring. I believe that the most critical research needs exist in four areas: (1) assessment approaches; (2) methods of making better use of auxiliary information; (3) indicator development; and (4) sampling designs.

Assessment Approaches

'Assessment is a process by which data are converted into useful information' (Palmer et al., 1992). There are many users (customers) of environmental

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monitoring information, and hence many possible assessment methods. It is important to have a strategy for conducting assessments; but it is equally important not to constrain assessment to a single model or method. When describing assessments, it is important to also describe the database and the assumptions used to make the assessment.

One common approach to assessment is a simple description of key ecosystem indices. Indices of ecosystem status and trend are computed from monitoring data. The values of the indices are reported either spatially (for points or regions) or temporally (for the same area over time). The values may simply be reported without judgment, allowing the users of the information to draw their own inference about the status of the indicator. This is one approach often used by NEFIA when producing State reports. Information on forest growth, mortality, and yield status and trends are reported with a minimum of discussion about whether the results are 'good' or 'bad'. Research can improve the descriptive approach by developing a valuation system which allows us to categorize values of environmental indices into 'good' or 'bad' values, or 'improving' or 'worsening' conditions. This helps us present the information to the non-specialist public in a manner that they can comprehend. More detailed information on status, trend, and problems are then prepared and presented for more technical audiences.

Another approach is risk assessment, a process of quantitatively analyzing risks associated with environmental problems (Graham et al. 1991). Such estimation of probabilities provides policy makers with a rational basis for weighing the costs and benefits of mitigating environmental problems. This approach is attractive because it puts environmental status or trend in an understandable context, allowing users to make judgments about unfamiliar risks by giving them a means of comparing the risk to other risks which they may understand better - for example, relating the risk of death associated with radon exposure to the risk of death associated with dental X-rays. Research is needed to develop cause:effect models linking environmental events (e.g. elimination of a species) with environmental problems (e.g. loss of habitat). Once such a model exists, further assessment can be conducted through sensitivity analysis. A typical sensitivity analysis involves a model with parameters derived from environmental monitoring activity. The model is used to play 'what if' games with the values of the parameters. For example, if we have a global carbon model linking land use change and the global carbon cycle, what is the impact of a 2% per year reduction in forest land over 20 years? The model allows us to assess the importance of the change in the context of the model assumptions.

A third type of assessment is cost:benefit analysis. This approach is increasingly favored by the political leaders in the US, who want to weigh economic costs and benefits of mitigating environmental impacts.. Here research is needed to rationally quantify the costs and benefits associated with changing environmental status and trend - a nontrivial task, given that many of the costs and benefits cannot be expressed in standard monetary terms. It is also crucial to study the distribution of costs and benefits - who pays the cost, and who accrues the benefits? Frequently the people bearing the costs are not the same as those who accrue the benefits, leading to moral issues in environmental justice.

Finally, research is needed to identify additional methods of assessment. A sound monitoring program will not limit itself to any single method of assessment; rather, it will examine monitoring data from the multiple perspectives of different assessment paradigms, to seek new inferences and discover new truths. Any program which forces all assessment into a single 'assessment paradigm' is at best doomed to report only partial truths.

Auxiliary Information

We cannot afford all of the information we would like to incorporate into assessments. There exist many other programs which collect data relevant to environmental assessment. A significant research need is to devise meaningful ways of incorporating auxiliary information - data from other sources - into a monitoring program. A classic example of auxiliary information is satellite imagery. There are many kinds of imagery available, each with different resolutions, availability, information content, and costs. The expertise required to manipulate this information is often very different from the expertise readily available in environmental monitoring projects. Without an extra effort, there is small chance of exploiting the data. The same can be said for a multitude of data available from other sources, e.g. agricultural, medical, climatalogical, industrial, and sociological data. It is often tedious to wade through all of the available

information; it is simpler to start from scratch and focus attention on what we ourselves need, even if some of that information may already be available elsewhere. However, this may be duplication which we cannot afford. We need to build and utilize tools to facilitate the search for useful data, e.g. the creation of 'meta-data', or 'data about data'.

Indicators

Indicator development is one of the more obvious needs of a monitoring program. Scientists are always interested in developing new procedures for studying ecosystems. However, it is important not to let the drive to publish new and 'innovative' science overwhelm the objective of the monitoring program. We have had a tendency for indicator developers to focus on developing the 'Ultimate Indicator' - a universal, comprehensive measure which completely describes their particular ecosystem dimension, e.g. 'soils'. The result is often a 'measurement suite' which is too expensive, too time consuming, and too complicated to be useful.

Indicator research should have two driving forces. First, sharpen the focus: determine what are the relevant aspects or dimensions of the ecosystem that we need to capture in order to conduct our assessments. There are a variety of statistical tools which look for associations among sets of measurements and identify information redundancy. It is worthwhile to identify the 'principal components', or dimensions of variation for the assessment objectives, and to focus on indicator development which gets at those dimensions. Rather than trying to design the 'perfect indicator' for a single dimension, we should allocate resources to develop acceptable indicators for all of the key dimensions, then improve the indicators over time.

For example, there are dozens of methods in the literature for quantifying the ecosystem dimension of 'species diversity'. Rather than waste resources trying to decide which of the many indicators of 'species diversity' are 'best', we should (1) identify the important dimensions of 'species diversity' that we need to capture - for example, species richness and species evenness; then (2) choose an adequate measure of each; then (3) move on to the next dimension of interest.

Secondly, we need practical, reliable, and useful methods of collecting data to quantify those dimensions. We must consider an appropriate way to classify a measurement, yet remain constrained by the practicalities of the monitoring system so that the resulting measurement can be implemented. Indicator development should be science based and customer driven: scientifically sound and defensible, but directed by the needs of the customers who determine the types of assessments that we are doing. Indicator development should involve an equal partnership among scientists, information managers, quality assurance specialists, and the people who will collect and analyze the data. It must be a managed process with a clearly defined goal, rather than simply an open ended research program.

Sampling Designs

Sampling theory is rich - some would say extravagant - with statistical sampling approaches for monitoring ecosystems. Some monitoring systems focus on very intensive measurements at a relatively small number of sites purposively selected to represent certain environmental conditions. Other approaches favor less intensive measurements spread out over a larger population of interest. Both approaches have merit and will be included in a well balanced monitoring program.

Intensive site monitoring supports research into mechanisms and models linking observable data to medium and long term changes in ecosystem status and function. This kind of research requires a traditional experimental design approach, controlling for variation to help establish and test cause-effect hypotheses. This kind of research should be an ongoing component of an ecosystem monitoring program.

However, it is not sufficient for monitoring purposes to study intensively a limited number of hand picked sites. Many scientists who conduct research at long term monitoring sites will attest to the uniqueness of the sites. While intensive site monitoring can be revealing about processes and linkages when we know what questions to ask, it fails to provide an adequate sample from the larger population of interest: the total environment. There is no scientifically valid way to make inferences about larger populations based on data from purposively selected experimental areas. If

the intent of the monitoring program is to make statements about the larger 'environment', then the samples must be drawn so as to represent that population. Sample designs can be improved by conducting pilot studies to quantify the variation - over space as well as over time - of the measurements of interest.

The present status of forest ecosystem monitoring in the US includes hundreds of intensive forest ecosystem monitoring sites supported by a variety of funding agencies including the National Science Foundation, numerous University research stations and forests, and study areas supported by National Parks and National Forests. However, there is presently only one extensive forest monitoring program covering all of the US: the US Forest Service Forest Inventory and Analysis (FIA) program. This program has monitored timber inventory for over 60 years; while it does not fully address all critical dimensions of forested ecosystems, it could be expanded to do so with additional funding. If we are looking for the best place to invest the next $10 million in forest ecosystem monitoring, we should invest in augmenting the extensive FIA system to include more ecological dimensions: for example, measurements of tree health, plant species diversity, lichen community stability, nutrient cycling, wildlife habitat, and wildlife populations. This would provide the critical extensive monitoring needed to balance the present investment in intensive ecosystem monitoring.

A successful monitoring program also needs constant research to make sure that the program remains relevant and sufficient to addressing the needs of the customers sponsoring the monitoring. The program itself needs to be monitored, with information fed back continuously into the process, so that the program maintains support and improves over time.

DEVELOPMENT NEEDS FOR FOREST ECOSYSTEM MONITORING

Ecosystem monitoring depends as much on development as it does on research. Development in this context implies using experience, knowledge, and research findings to build and integrate key components into an overall program. This is not research in the classic sense of 'discovering previously unknown information'; yet it often does involve putting existing information together in often pioneering ways in order to produce a process which most efficiently meets the demands of the monitoring system. Development is equally as important as research, and the monitoring project itself is an exercise in both research and development. There are three areas of development which are crucial to a productive ecosystem monitoring system: information management, quality assurance, and reporting.

Information Management

Information is both the raw material and final product of a monitoring system. In many cases, information is the most important resource which we manage. Information management is a science, yet the development and management of information management systems is often left up to 'amateurs' - scientists, managers, and technicians with no formal training or experience in managing information. This frequently leads to inaccessible or error-laden data and a failure to meet customer requirements. A superior approach to developing information management systems is to have a team made up of scientists, managers, and analysts, with leadership and staffing by trained computer scientists.

An ecosystem monitoring program is liable to have complex data management needs. Any monitoring program will probably be unique enough so that there is no 'standard' information management solution. A research need is to treat the development and operation of a database as a research process. There needs to be a study plan, called a 'requirements document', which models the 'business' of the data according to how they are collected and used. In most cases the database will be relational, with data collected and cross referenced at different scales (e.g. forest, plot, tree, branch level data). The system should include a set of checks and references to ensure that data are collected and entered properly. Changes made to the data need to be documented. Missing data (and there will always be missing data) need to be identified, even when estimates are substituted. Validated data must be accessible to interested users, in a format which is easily usable yet which imposes some discipline upon the user to become familiar with the overall monitoring program. There is a fine line between making data readily available to users willing to invest the time to learn about the data, but also protecting against misanalysis and abuses by uneducated analysts.

Quality Assurance

Quality assurance commonly refers to activities implemented in order to build confidence in the accuracy, precision, representativeness, completeness, and comparability of collected data. There is a large body of literature dealing with quality assurance, mostly for manufacturing or laboratory processes. We can also apply the principles of quality assurance to ecological monitoring (e.g. USDA Forest Service Northeastern Station 1994). There are many activities which can contribute to a quality assurance program, for example training, documenting methods, and conducting audits by experienced check crews. The greatest development needs are for practical methods of incorporating quality assurance philosophies and results into a field monitoring program.

We need to specify the desired quality of measurements. The desired level of quality is defined chiefly by the use to which the data will be put. A typical measurement quality objective consists of a maximum allowable error in a measurement which is acceptable a certain proportion of the time. Measurement quality objectives should be established for all measurements, whether quantitative or qualitative. The objectives can be used as measures of success or failure in a variety of activities, for example training of crews, data collection techniques, or data collection activities. Failure to meet measurement quality objectives can be addressed through increased training or refined measurement methods; or the objectives themselves may be relaxed if deemed excessive for assessment needs.

Another development need is for timely and informative means of analyzing data quality. Most monitoring systems include some level of duplicate measurements taken to gauge the effectiveness of data collection systems. Statistical analysis of resampled data can be used to assess the reliability of various parts of the system, for example the precision of the measurement process, the reliability of the crews, or the variation inherent in the variables of interest. Information from this analysis is invaluable in improving the measurement and training process over time, leading to continuous improvement in the monitoring system.

Reporting

Many monitoring programs focus the majority of resources on planning, organizing, and implementing data collection. Data collection attracts the most urgency because we fear the consequences of 'failure to collect', which may lead to gaps in the data. This is particularly true in ecosystem monitoring programs which depend on some sort of sampling window, e.g. a summer growing season or a spring wet season, where failure to be ready at the start of the window can mean losing a year of data. The drawback is that we often wind up sitting on great piles of data which we never have the time to fully analyze. Therefore the third major development need is for a system of reporting which has the resources to operate independently of the data collection activities, and which is constantly making information and assessments available to a variety of users.

It is important to recognize the variety of users. Peer reviewed papers in professional scientific journals are important because they serve as the basis of scientific credibility for the monitoring program. However, such publications alone generally have little impact on society. Impact is a result of scientifically credible information delivered to people who need the information, in a form that they can use. Peer reviewed publications are necessary, but not nearly sufficient, to generate impact. Also required is making information available in popularized reports, press releases, brochures, media interviews, and Internet World Wide Web homepages.

Critical development needs are (1) to identify all of the potential customers of the information obtained from the monitoring program, and (2) make sure that they get the information from the ecosystem monitoring program, in a format that they can understand and use. Potential customers include politicians, journalists, industry associations, managers, scientists, and the general public. Failure to reach the full range of customers results in loss of support for the program, and eventual program termination.

TYING IT ALL TOGETHER - CONTINUOUS IMPROVEMENT

I have made the argument in this paper that an ecological monitoring program is an exercise in applied research. There are distinct research needs for new methods of assessing environmental data; for including existing auxiliary data; for identifying and developing methods to measure important components of variation; and for development of sampling designs which optimize sampling efficiency. In addi-

tion, there are development needs: for professional, reliable information management systems; for assessing the quality of monitoring information; and for disseminating the results of the monitoring program across a broad spectrum of users.

The greatest research need is to avoid trying to separate 'research' from 'monitoring'. A research function is a necessary component of successful ecosystem monitoring. A monitoring system needs to evolve, adapting and improving continuously as new information about the system is uncovered and as new demands are imposed by customers. The system cannot be allowed to evolve randomly; there needs to be balance between the research and development components. Ideally there should exist some core elements of the program, for example a sample frame and a base set of measurements, which do not change over time and which allow linkages between historical information and new questions. There needs to be a management process to allow the continuous improvement of the monitoring process. A strong research component - constantly assessing current information and seeking ways to improve the effort - is critical to the long term success of an ecological monitoring program.

Finally, in the current debate over the needs for intensive vs. extensive monitoring of forested ecosystems, it is clear that most knowledgeable people accept the need for both types of monitoring: extensive monitoring for reporting on the status of populations and generating hypotheses about change, and intensive monitoring for testing hypotheses and fine tuning measurement techniques. The debate is about resources: where to invest our monitoring dollars. In the case of forested ecosystems, it is clear that most of our resources are presently invested in hundreds of intensive sites scattered across the country according to numerous local needs. There is no analogous extensive system to monitor a variety of major forest ecosystem attributes across all US forested land. Such a system could be built out of existing systems if more resources were made available. Such a system is clearly the greatest present need. The best investment for the next $10 million in forest ecosystem monitoring would be to complete the work done initiated by the Forest Health Monitoring program, integrating holistic ecosystem monitoring concepts into the existing Forest Inventory and Analysis program. If we fail to do this, we will never become proactive in detecting and addressing changes in ecosystem status and trend; rather we will forever be reacting to problems, real and imagined, brought to our attention by the public that we are supposed to serve.

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Forest Inventory and Analysis (FIA) Variables: Indicators of Ecological Integrity?

David C. Chojnacky[1]

Abstract.—The U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis (FIA) program has conducted extensive forest inventories for over 65 years. FIA was initially created to report forest area and timber supply for the nation, but FIA has recently devoted attention to more comprehensive forest resource assessment. This paper offers an ecological framework for overviewing 300 variables produced by the FIA program in the Interior Western United States (INT-FIA). To facilitate the overview, variables are grouped into (1) soil stability/watershed variables, (2) nutrient cycling/energy flow variables, (3) recovery mechanism variables, and (4) disturbance variables to assess usage as indicators of ecological integrity. Several representative variables are illustrated by using FIA data from pinyon-juniper forests in New Mexico, U.S.A. Statistical confidence intervals are used to assess the examples. Results show INT-FIA's two-phase sample design provides an opportunity for monitoring some ecosystem processes by emphasizing tree variables. A recommendation is given for emphasizing six tree variables—diameter, diameter growth, tree age, height, status/history, and species identification—that are currently measured in INT-FIA inventories but could also be useful indicators for monitoring.

INTRODUCTION

The health or ecological integrity of wildlands is an important issue today. Shifts in public values and changes in the natural resources disciplines have fueled concerns that single-use management practices such as timber harvest or domestic grazing should be considered in terms of the effects to the entire ecosystem. Managers need effective tools to monitor ecological impacts of management activities.

One way to meet this need is to create monitoring programs, such as the U.S. Environmental Protection Agency's Environmental Mapping and Assessment Program (EMAP) (Hunsaker and Carpenter 1990). But existing inventory programs could also possibly be restructured to provide more monitoring information. One example is the U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis (FIA) program, which has conducted regional forest inventories since 1928. FIA initially provided a nationwide survey of forest area and timber supply. Prompted by environmental laws passed in the 1970's and 1980's, increasing forest resource conflicts, and a growing awareness of complex ecological interactions, the FIA program has expanded beyond timber assessment (McWilliams 1995; Rudis 1991; USDA 1993). Recent additions increased from 60 to more than 150 the number of resource variables gathered, processed, and stored for each FIA field plot (Powell and others 1994). Many of these new variables are categorical and aimed at land use questions such as grazing intensity, wildlife use, soil erosion, burn history, and many other land impacts.

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This paper examines FIA inventories for use in monitoring wildland health. Could some of the new and older FIA variables be used as indicators of ecological integrity? This question is explored in the context of an actual FIA inventory conducted in 1986 and 1987 in pinyon-juniper woodlands in New Mexico, U.S.A. (Van Hooser and others 1993). Because some differences exist among the six FIA programs in the United States, all analysis and discussion apply specifically only to the Interior West FIA program (INT-FIA), which conducted the New Mexico inventory. However, enough similarity exists among FIA programs that general findings could apply to all units.

This paper does not focus on the details of every INT-FIA variable measured. Instead, variables are grouped into four broad categories (phases), and some example variables from each phase are roughly assessed for their potential as indicators. Except for use of statistical confidence intervals, the variable examination is not highly quantitative.

MONITORING TERMINOLOGY

Monitoring terminology is value-laden and sometimes confusing, but West and others (1994) have sifted through much of it to establish common ground. According to West, *indicators* are characteristics or attributes chosen to be measured for monitoring. This does not mean that anything one chooses is necessarily a useful indicator. Indicators must be associated with some value system; then their usefulness can be judged. For this paper *ecological integrity* is the basis of the value system. Integrity has been defined as "possessing a full set of natural parts and processes in good working order" (Leopold 1949; Salwasser and Pfister 1994; West and others 1994). Based on that, *indicators* of *ecological integrity* could be defined as "characteristics chosen to measure ecosystems to ensure that a full set of natural parts and processes are in good working order."

A National Research Council (1994) report on rangeland health gives a practical interpretation of ecological integrity. The report breaks the first part of the integrity definition—natural parts and processes—into three phases: (1) a soil stability and watershed function, (2) nutrient cycling and energy flows, and (3) recovery mechanisms. The Council defines the other part of integrity—the assessment of "good working order"—in terms of healthy, at risk, and unhealthy.

The three phases in the National Research Council scheme are intended to evaluate the complex biotic and abiotic factors that drive change in terrestrial ecosystems.

- Soil/watershed phase. The soils are the storehouses and living systems where physical, chemical, and biological process link to nutrient cycles and energy flows. Of concern for monitoring are soil degradation, capture of precipitation, and soil surface condition.
- *Nutrient/energy phase*. The availability of nutrients from the soil and energy from the sun determines the status of the plants that are the producers of the terrestrial food chain. Nitrogen, carbon, and other nutrient cycles and photosynthesis are key processes. Of concern for monitoring are plant community and species structure, plant and litter distribution, and net primary production of plants.
- *Recovery phase*. For ecosystems to be healthy or evolve toward a more healthy state, recovery mechanisms must be in place. Of concern for monitoring are factors that affect plant demographics such as age-class distributions, plant vigor, and seedling establishment.

For this paper, the National Research Council's three phases are used to group INT-FIA variables as indicators of "natural parts and processes" (the first part of the integrity definition). A fourth phase for *disturbance* indicators is also included because INT-FIA collects a number of variables on nontimber resources that do not fit the other three phases, but these variables all relate to natural and anthropogenic disturbances.

Before implementing INT-FIA variables as indicators, the variables also should be examined for usability as measurements of "good working order," which is risk assessment. Risk assessment is not attempted in this paper, but if it were to follow Natural Research Council guidelines, values of INT-FIA variables would need to be ranked as healthy, at risk, or unhealthy in relation to processes being monitored.

BACKGROUND ON INT-FIA INVENTORIES

For any use of INT-FIA variables as unbiased estimators, the variables must be compiled within a sampling context. Use of the sample design also allows computation of confidence intervals that measure statistical reliability or precision for every estimate calculated. A full description of INT-FIA's sample design is being documented elsewhere (Chojnacky [in preparation b]), but a short summary follows.

INT-FIA inventories use a probability-based design called two-phase sampling, where a first-phase photo sample is subsampled with second-phase field plots. It is similar to double sampling for stratification (Cochran 1977), but it is a little more general in its application.

Three concepts—*totals*, *attributes*, and *categories*—are essential to compiling data with the two-phase sample design. Population or subpopulation *totals* are the primary estimates reported for INT-FIA inventories. Unlike many other sampling designs, population *means* cannot be directly estimated within the two-phase design; another ratio estimator is needed. Totals for area, volume, mortality, and growth of trees are commonly reported by INT-FIA, although totals can be compiled for any variable that is also an *attribute*.

An *attribute* (Y) is generally a continuous variable, as opposed to a *category* © variable, which is discrete. An exception to this definition is the attribute forest area that is used as a discrete binomial variable in the two-phase design (by assigning $Y = 1$ if a second-phase plot has the category of interest or $Y = 0$ otherwise).

Attribute totals are often sought for subsets of a population, which are defined by using categorical variables. The defining of subpopulations is the primary usage of categorical variables in the two-phase design. For example, categorical variables such as forest type, ownership, county, stand size, species, diameter class, and so forth are commonly used to estimate subpopulations of interest for volume, growth, area, or other attributes. In formal sampling theory, these subpopulations identified by categorical variables are called "domains of study" (Cochran 1977, p. 34).

The distinction between attribute and category variables can be confusing when considering raw measurement variables because many attribute variables can also be classified into useful category variables, but the converse is not possible (with category variables that are initially observed in discrete classes). For example, tree diameter can be used as an attribute variable to calculate basal area, and it can also be used as a category variable to calculate discrete diameter classes. On the other hand, discrete observations such as tree disease, forest type, or soil erosion can only be used as category variables within the two-phase design.

The general formula for estimating attribute totals for subpopulations is:

$$\hat{Y}_c = N\bar{y}_c \qquad (1)$$

where

$\hat{Y}_c$ = attribute total for category c in subpopulation of interest

$\bar{y}_c$ = attribute for category c averaged over population from all strata

N = total area of population

An additional ratio estimator is used to estimate attribute means because the sample mean ($\bar{y}_c$) in two-phase sampling is always averaged over the entire population, including nonforest as well as forest land. Because most sample means of interest are usually for subpopulations, a mean is computed from a ratio (R) by dividing a subpopulation total by a corresponding area total:

$$\hat{R} = \frac{\hat{Y}_c}{\hat{Z}c} \qquad (2)$$

where

$\hat{Y}_c$ = attribute total for category c in subpopulation of interest

$\hat{Z}_c$ = forest area of $\hat{Y}_c$ for subpopulation of interest

Estimates such as mean volume per hectare can be computed from this ratio. The ratio is also useful for estimating attributes measured as proportions such as percent canopy cover. Because proportions cannot be *totaled* into meaningful estimates, the ratio is necessary to estimate population proportions within the two-phase sampling design.

In summary, the usage of INT-FIA variables in the two-phase design requires a distinction between attribute (Y) variables and category © variables. This distinction is important because totals and confidence intervals can only be computed for attributes (Y) within the two-phase sampling framework. The category variables (c) only serve to identify subpopulations for attributes of interest.

ASSESSING INT-FIA VARIABLES FOR POTENTIAL AS INDICATORS

The inventory used for this study included pinyon-juniper lands mostly outside National Forests in New Mexico (fig. 1). Data included 1,081 field plots from a 1986 to 1987 INT-FIA inventory (Van Hooser and others 1993). Field plots were selected from 3.5-, 5-, or 7-km grids used to subsample from a 1-km grid of photo plots in the two-phase design. National Forest data, except the Lincoln National Forest, did not include all the INT-FIA variables and were therefore excluded from this study. More than 300 variables were available from 113 field measure-

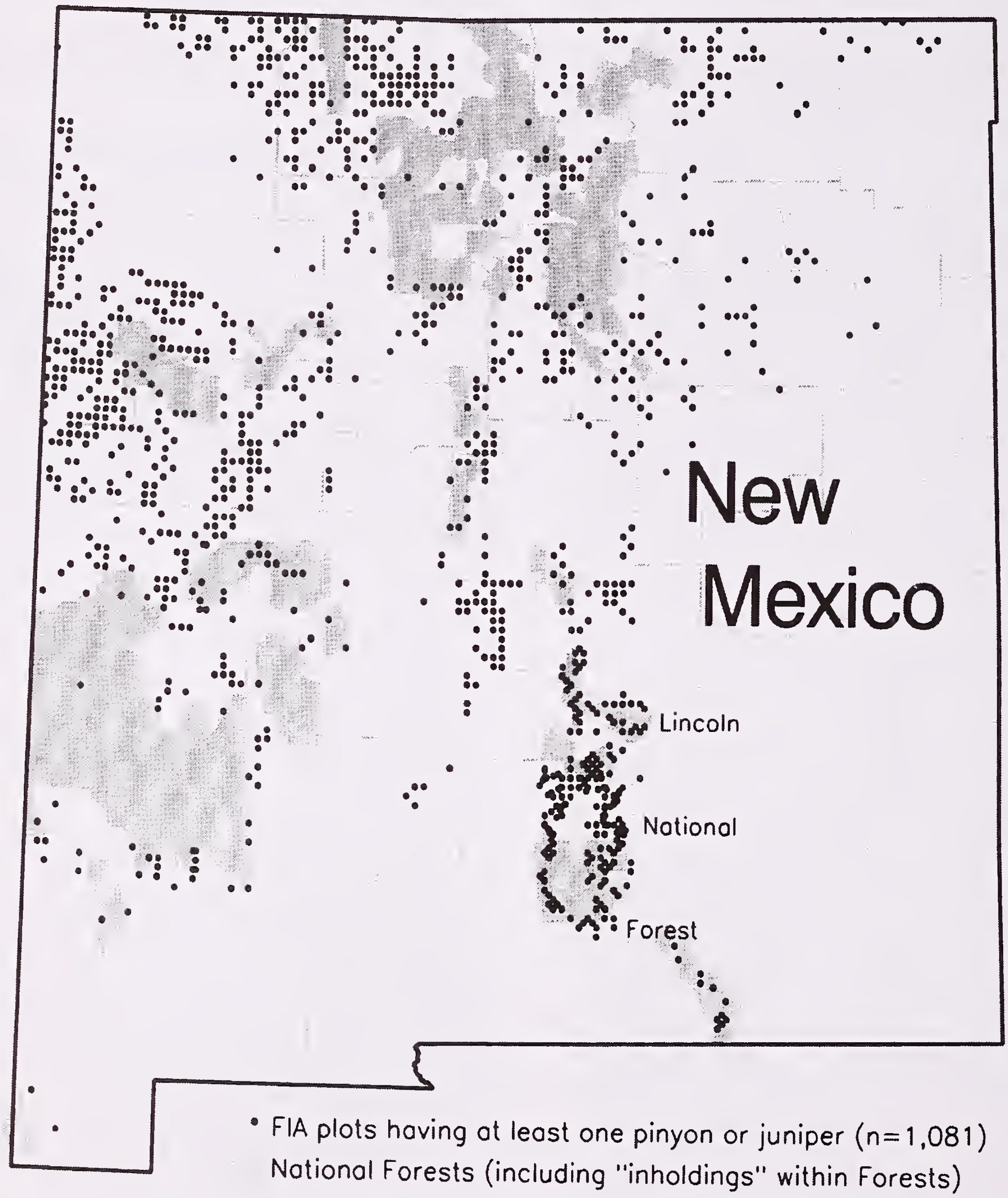

Figure 1. Location of pinyon-juniper plots sampled, in 1986 and 1987, from the Lincoln National Forest and from all other lands outside National Forests.

ments that included 67 plot or tree measurements, 30 multiresource measurements, and 16 understory vegetation measurements (USDA 1986).

Framework for Identifying Variables

From the 300 variables, those relating to resource measurements were separated from other variables used to identify, track, and compile resource statistics in the two-phase sampling design. Among the resource variables, a list of 47 variables were identified as more or less unique measurement concepts. The idea was to identify all variables that related to forest resources, but to avoid duplicate descriptions of a particular process, function, or dimension. For example, INT-FIA calculates more than 25 volume/biomass/growth variables in net, gross, cubic, and board foot units, but only three volume/growth variables were identified as unique concepts. Left out of the list of unique variables were those that required complex modeling from other variables.

Next, the 47 variables (table 1) were matched with definitions for indicators (the three phases) given by the National Research Council (1994). Those variables not fitting Council guidelines were placed into a "disturbance phase." Variables were subgrouped into *attributes* or *categories* according to their usage in INT-FIA's two-phase design. For example, topographic variables are actually measured as continuous variables by INT-FIA and could technically be used as attributes, but INT-FIA's 3- to 7-km sample grid is not intense enough for such use. Furthermore, attribute data for topographic information are readily available in digital format from other sources at 60- to 90-m resolution (Weih 1991).

Precise evaluation of table 1 is not intended because of subjectivity involved in matching variables to phases, but some trends can be observed. Because almost half of the variables fall in the nutrient/energy phase, few variables exist to monitor soil/watershed functions and recovery mechanisms. Because nearly 75 percent of the variables are categorical, this shows a greater emphasis on discrete observation of resource characteristics as opposed to lesser emphasis on measurement of continuous resource attribute variables.

Statistical Confidence Intervals

Of all the factors that could be considered in assessing each variable in table 1 as an indicator, statistical reliability or precision (in terms of confidence intervals) makes a useful starting point. If a variable cannot be estimated with some reasonable degree of precision for detecting change from repeated remeasurement, then further evaluation of that variable seems pointless regardless of its scientific value.

Table 1. Forty-seven variables divided into four phases described the breadth of resource information in an INT-FIA inventory. *Attribute* and *category* variable types correspond to variable usage in the two-phase sampling design.

	Phase 1 soil stability/watershed		Phase 2 nutrient cycling/energy flow		Phase 3 recovery mechanisms		Phase 4 disturbance	
Variable type[1]	*Attribute*	*Category*	*Attribute*	*Category*	*Attribute*	*Category*	*Attribute*	*Category*
Plot or tree variables		elevation aspect slope physiography	forest area diameter/basal area height crown ratio volume number of trees crown cover	humus litter stand size forest size forest type habitat type species	basal area growth age	seed source		harvest stand orgin damage disease
Multiresource variables		bare soil soil erosion soil texture soil depth soil group water proximity	snags down trees	veg. concealment wildlife cover				access animal use browsing grazing fire land use recreation roads/trails
Understory vegetation variables			canopy cover	layer height life form species				
Total variables	0	10	10	12	2	1	0	12

[1]An INT-FIA label used to organize variables in field procedure guidelines.

In general, FIA reports variance estimates (needed for confidence intervals) for only a few individual variables at Statewide population levels. However, additional confidence intervals for any subpopulation, defined by categorical variables, could be computed from the INT-FIA data base.

Even though confidence intervals are easy to compute, an exhaustive method to assess precision for INT-FIA variables is difficult to devise because each variable could be used in numerous combinations to subset data, and each combination will have different variance (precision) estimates. Therefore, only a few representative cases were examined for each phase of variables.

Soil Stability/Watershed Variables

Because there were no attribute variables for this phase, forest area was combined with the category variable for percentage classes of bare soil. Also included with forest area and bare soil was a tree species variable so that amount of bare soil could be compared between different subpopulations of tree species (fig. 2).

Although not commonly done, tree species may be used to subdivide forest area, or any other attribute, if the data are viewed as a statistical distribution for each species. This was done by proportioning (weighting) the attribute data on each plot by basal area (for all trees 7.6 cm basal diameter and larger). For example, a plot that is 30 percent pinyon basal area and 70 percent oneseed juniper would associate 30 percent of a plot's attribute with pinyon and 70 percent with oneseed juniper. Some might criticize this approach because forest area is traditionally associated with forest types or some classification corresponding to actual plot conditions instead of statistical distributions for entire populations. However, a species subdivision of INT-FIA data is simple—no complex classification algorithms are needed—and it is an easily defended classification for regional inventories. Often forest types or more complex vegetation

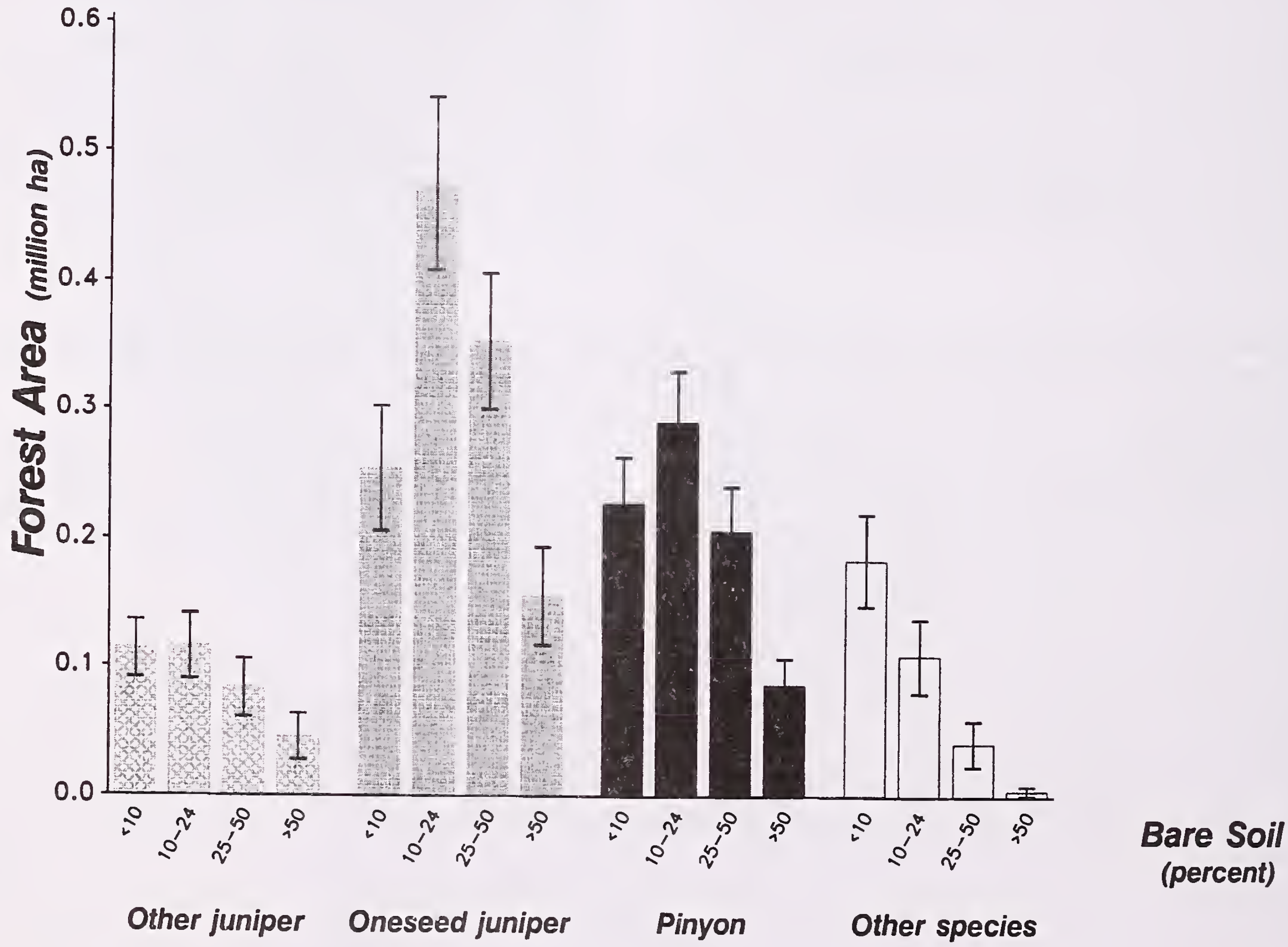

Figure 2. The attribute forest area (and 95 percent confidence intervals) categorized by amount of bare exposed soil and by species. Data are from the Lincoln National Forest and all lands outside National Forests in New Mexico, 1987.

classifications cause problems for Statewide or regional inventories because of knowledge gaps or regional definition differences. A species-based classification avoids these problems.

For the New Mexico pinyon-juniper examples, four species groups were used to classify all data. The four groups were oneseed juniper (*Juniperus monosperma*), pinyon (*Pinus edulis*), other junipers, and all other species. Oneseed juniper and pinyon pine were the two most common species. The "other junipers" included Rocky Mountain juniper (*J. scopulorum*), alligator juniper (*J. deppeana*), and some Utah juniper (*J. osteosperma*). The fourth group included all "other species" associated with pinyon-juniper in New Mexico: ponderosa pine (*P. ponderosa*), Gambel oak (*Quercus gambelii*), aspen (*Populus tremuloides*), and other mixed conifers.

Statistical summarization of New Mexico's forest area by bare soil and species categories showed most 95 percent confidence intervals ranged from 14 to 25 percent of the bar totals for pinyon and oneseed juniper (fig. 2). To judge if these are small enough to detect changes in a monitoring situation, a simulation comparison was done. For half of the plots (shown in fig. 2), an additional 15 percent was added to the bareground estimate. Comparison of these data to the original data showed little overlap in the confidence intervals ("a" versus "b" in fig. 3), indicating that a 15 percent increase in bare soil for half the plots could be detected within INT-FIA's sampling framework. This does not substantiate whether area of bare soil is a useful indicator for monitoring, but it does indicate promise for further study.

To more fully judge bare soil as a useful indicator of soil/watershed processes, percent bare soil would need to be consistently estimated among crews, be repeatable over time, and be a key factor in soil stability. Quality assurance and further biological study are beyond the scope of this paper, but INT-FIA's two-phase design seems a suitable framework to monitor variable combinations such as the area of bare soil associated with each tree species.

Several other categorical soils variables were also examined, and statistical results similar to those for bare soil were found.

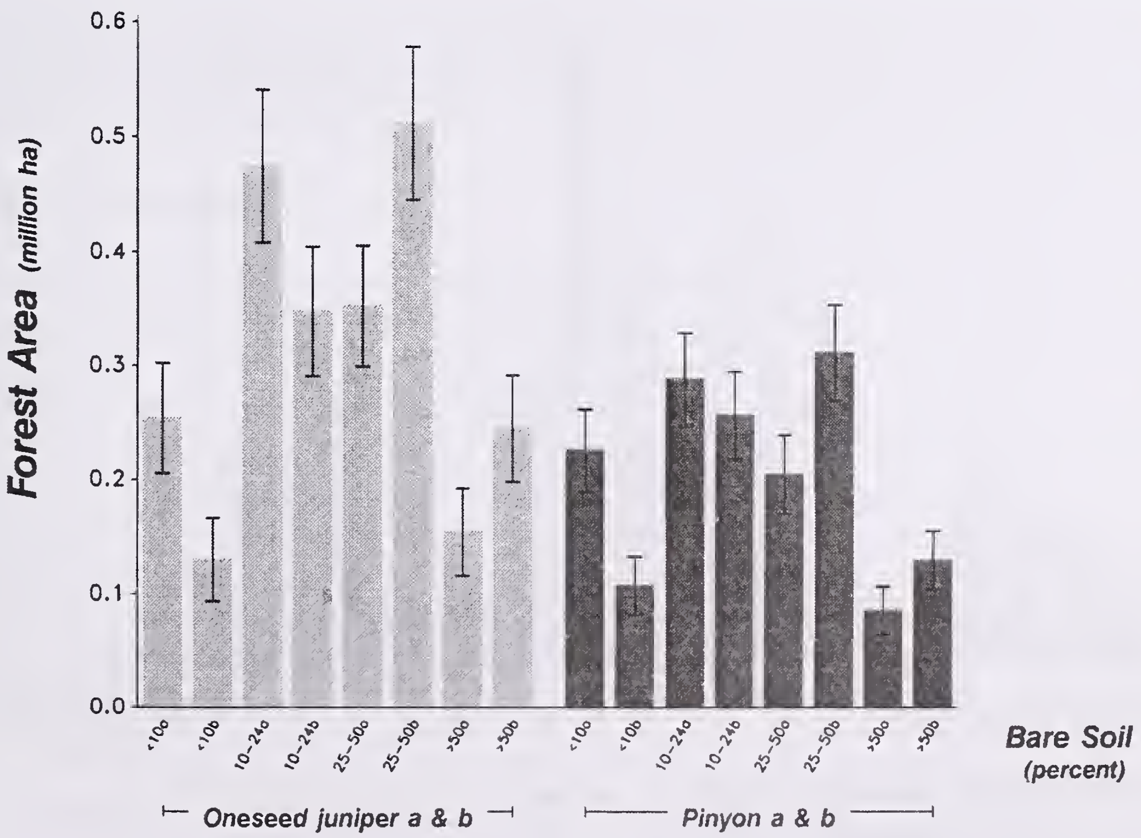

Figure 3. Comparing amount of bare soil "a" to simulation "b", where simulation "b" was obtained by adding 15 percent bare soil to one-half of the plots. The simulated increase in bare soil could be detected for those classes where 95 percent confidence intervals do not overlap for "a" and "b".

Nutrient Cycling/Cnergy Flow Variables

Most of the INT-FIA variables fit into this phase, which is designed to monitor plant distribution, litter cycling, root distribution, and photosynthetic activity (table 1). However, the INT-FIA variables are more heavily weighted toward "standing crop" analyses as opposed to productivity, turnover, cycling, or other nutrient/energy processes.

Two combinations of variables for overstory and understory vegetation were examined. For the overstory, tree data for live and dead volume were summarized within diameter classes by species. Live pinyon and juniper trees often include substantial amounts of dead wood that are tallied by INT-FIA in addition to completely dead-tree tally. The 95 percent confidence intervals for pinyon and oneseed juniper ranged from 10 to 20 percent of total live and dead volumes for most diameter classes (fig. 4).

For understory measurement, INT-FIA field crews ocularly estimate canopy cover for forb, grass, and shrub life forms and for some species. Using the ratio estimator (eq. 2), percent understory cover was estimated by life form. The 95 percent confidence intervals for grass and shrub cover ranged between 12 to 16 percent for the pinyon and oneseed juniper subpopulations, indicating reasonably precise cover estimates (fig. 5).

As mentioned for the soil/watershed phase, measurement repeatability and direct linkages to ecological integrity would have to be established before accepting volume and understory cover as indicators. However, their confidence intervals are reasonably small, which is necessary for detecting change in repeated remeasurement.

Several other variables in nutrient/energy phase were also examined, and similar statistical results were found. Variables in this phase that would be easy to justify as credible measurements are the

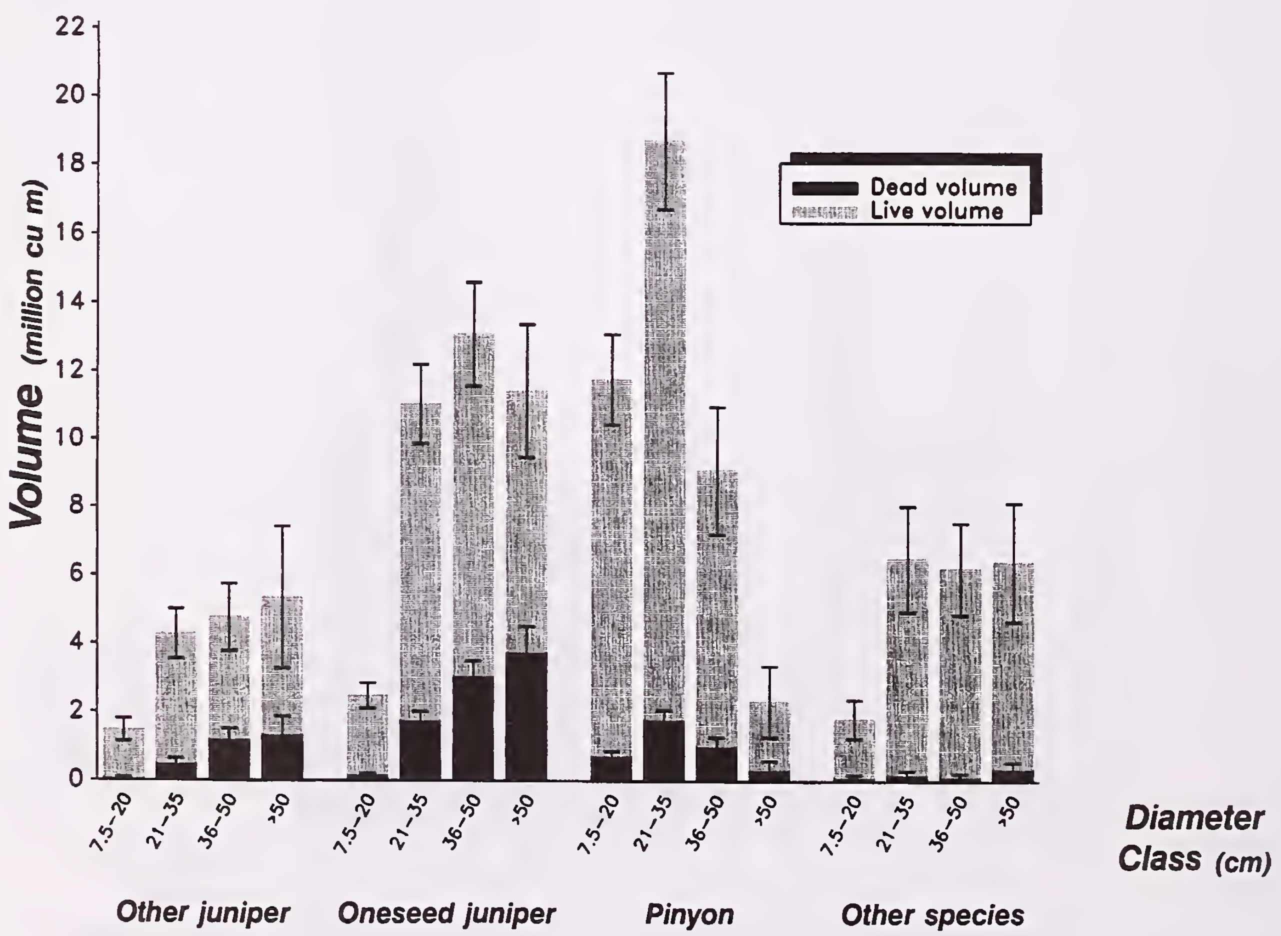

Figure 4. The attributes live and dead volume (and 95 percent confidence intervals) categorized by diameter class and by species. Data are from the Lincoln National Forest and all lands outside National Forests in New Mexico, 1987.

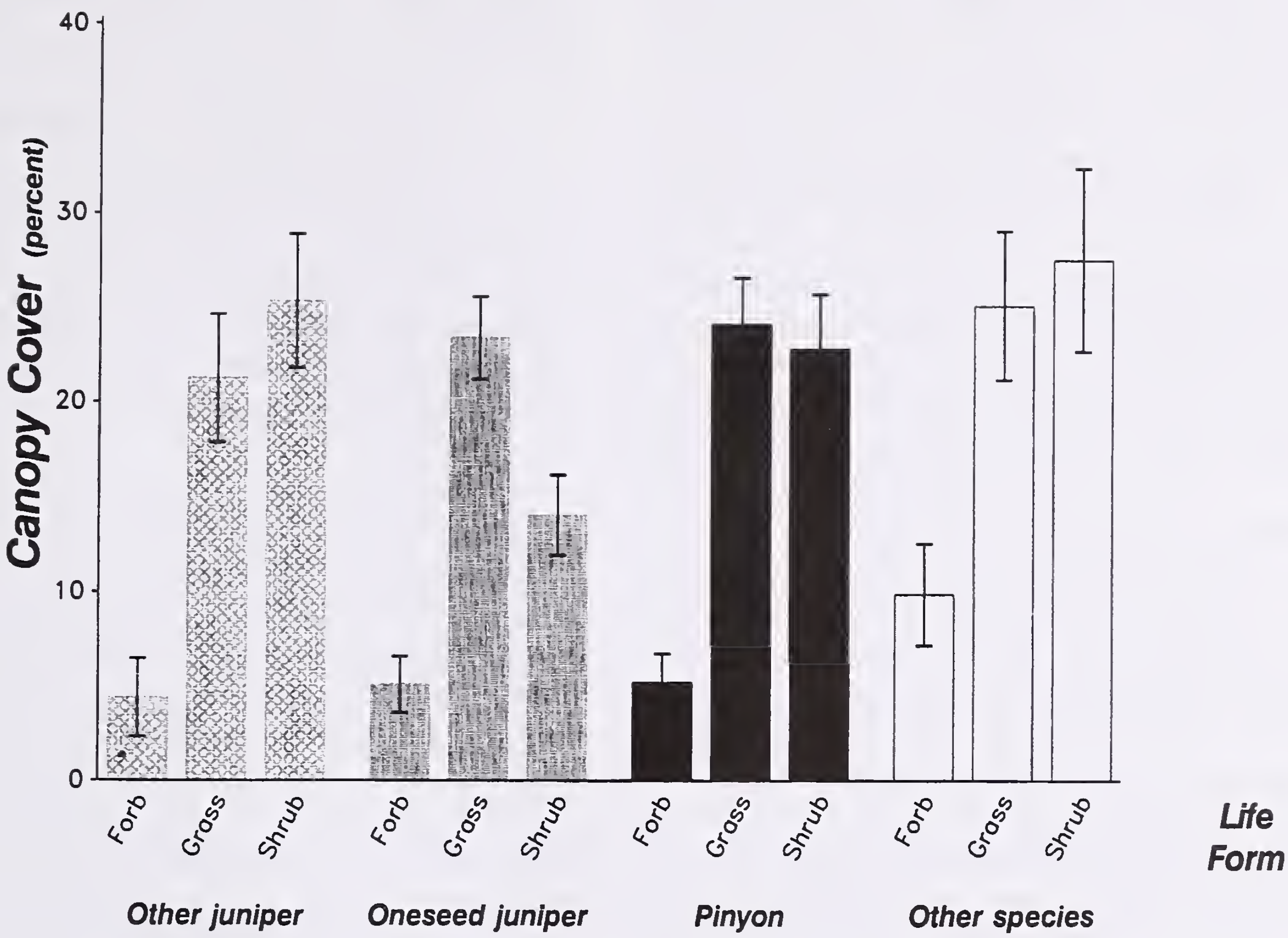

Figure 5. The attribute understory canopy cover (and 95 percent confidence intervals) categorized by life form and by overstory tree species. Data are from the Lincoln National Forest and all lands outside National Forests in New Mexico, 1987.

traditional timber measurements such as basal area, numbers of trees, and forest area that have a long history of objective technique development.

Recovery Mechanism Variables

This phase is intended to measure age distributions, plant vigor, and germination potential. INT-FIA measures growth and age, but these are subsampled in different ways depending upon several factors. Growth and age are particularly troublesome measurements for pinyon-juniper and intermediate models have been devised (Chojnacky [in preparation a]). The attribute basal area growth was examined by diameter classes among the species categories. Results were similar to those found for the volume analysis (fig. 4) and are not shown.

Disturbance Indicators

These variables do not fit into the National Research Council's scheme, but they are mentioned because INT-FIA uses variables such as these in collecting data on nontimber resources. INT-FIA does not measure any disturbance attributes, but categorical disturbance variables could be combined with other attributes. Tree damage/disease and grazing variables were examined, but results seemed uninformative. This is not too surprising because most disturbance variables are often aimed at specific resource questions that likely require different sample designs for each variable. Furthermore, most disturbance events are probably too patchy, clustered, or infrequent to reasonably sample with the 5-km grid used by INT-FIA.

If disturbance is to be measured with INT-FIA data, it should probably be done with attribute variables instead of category variables.

CONCLUSIONS

The breadth of available INT-FIA variables for assessing ecological integrity was examined by grouping variables into phases describing soil/watershed, nutrient/energy, recovery, and disturbance processes (table 1). Although only a start, this exercise showed

INT-FIA's strengths lie in the nutrient/energy phase. From a list of 47 potential variables, 12 were identified as *attributes* that can be estimated alone with statistical confidence intervals. The other 35 variables were *categorical* and must be used in conjunction with an attribute variable if summarized within the two-phase design.

From the pinyon-juniper examples discussed, estimates having 95 percent confidence intervals at about 10 to 25 percent of totals could be expected for INT-FIA data when data are divided into subpopulations using three or four variables. Therefore, INT-FIA data should be useful for detecting changes on Statewide subpopulations. Determining what level of change can be detected will require more study, but the general framework of INT-FIA inventories appears useful for monitoring. For example, a 15 percent change, simulated on half the plots, was detected for the bare soil example (fig. 3).

The primary shortcoming among INT-FIA variables was a lack of attributes describing ecosystem processes. Timber-related variables such as volume and growth accounted for most of the attribute variables. Most of the nontimber variables were categorical and were devised to observe processes such as disturbance, soil properties, or other forest characteristics difficult to measure objectively. Morrison and Marcot (1995) and Iles (1994) warn against too many categorical variables for long-term inventories because the questions and needs are likely to change over time, making interpretation of data based on outdated categories difficult. Instead they advocate "attribute-driven inventories" where variables and inventory design are based on individual environmental characteristics rather than based on categorical variables having fixed definitions.

RECOMMENDATIONS

Although INT-FIA is not primarily a monitoring program, its overall framework appears adequate to objectively monitor ecosystem processes on a regional scale. Given INT-FIA's current two-phase design and its historical strengths, it probably makes sense for INT-FIA to focus on monitoring trees by emphasizing nutrient/energy (phase 2) and recovery (phase 3) processes. At this time, considerable research and development would be necessary to incorporate attributes on soils (phase 1) and disturbances (phase 4) into its design. But INT-FIA could emphasize a quality tree monitoring program with just the following variables:

- species identification of all trees
- tree diameter of live and dead trees
- diameter growth of all live trees
- age of all live trees
- tree height of all trees
- a tree status/history classification that would rate a live tree's disease or damage and rate a dead tree's degree of decomposition

These variables are already among INT-FIA's current measurements, but some modification and extension would be necessary to assess trees more fully in a biological context. For example, tree diameters should be measured for all tree species regardless of growth form; and consistent adjustment techniques should be developed to express all trees on a similar diameter basis whether sapling or large tree, whether measured at breast height (dbh) or at groundline near root collar (drc), or whether standing or down.

Repeated measurement of the six key variables would enable monitoring of structure, growth, and species composition of forest populations in terms of statistical distributions. This would provide baseline trends in forest carbon accumulation, productivity, and tree species diversity. Although these six variables do not fully cover National Research Council recommendations for nutrient/energy and recovery processes, they would likely be the basis of a popular data base if they were readily available and remeasured at 10-year intervals for all tree species on all land ownerships in the Interior Western United States.

Future research and development needs for a INT-FIA tree monitoring program include adding a few new variables and further study of a better analysis framework. Among the six tree monitoring variables mentioned above, there is no way to estimate spatial distribution among trees nor to estimate foliage parameters. Research into quantifying tree spacing patterns and measuring leaf area index or other crown metrics would be worthwhile. Also, further research into understory vegetation assessment would be worthwhile to give a complete assessment of all plant vegetation. INT-FIA has routinely collected understory cover data for almost 15 years;

little has been done with the data, but this would likely change if more research and development were conducted for understory vegetation.

Finally, analysis methodology of INT-FIA data needs further study. Recently, Schreuder and Thomas (1991) discussed the pros and cons of using INT-FIA data to establish "cause-effect" relationships. They concluded that cause-effect analysis was possible with appropriate safeguards for adequate variable definition, large enough sample size, and so forth. However, they did not suggest statistical methods for such analysis.

For INT-FIA's current use of two-phase sampling, the fundamental statistical outcome is a single point estimate and its precision, as illustrated by a single "bar" in figures 2 to 5. Comparison of two bars or comparison of the same bar over time involves potentially complicated spatial and temporal covariance components not included in INT-FIA's use of two-phase sampling. In other words, merely comparing bar charts is somewhat simplistic and could lead to misleading conclusions. Something analogous to extending the simple t-test to a more complex analysis of variance is probably needed. A possibility includes generalized linear mixed models (Wolfinger and O'Connell 1993), a recent extension to generalized linear models (Nelder and Wedderburn 1972). This model framework may link traditional sampling theory framework to models that could accommodate the spatial and temporal structure of INT-FIA data.

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Evaluación de Recursos Naturales y Necesidades de Investigación y Desarrollo: Experiencias y Perspectivas del Instituto Nacional de Investigaciones Forestales y Agropecuarias.

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La evaluación de los recursos naturales de México es una actividad que se ha desarrollado de manera formal desde hace varias décadas, empleando para ello diferentes técnicas. En los últimos años se han empleado herramientas que permiten un conocimiento de estos recursos de manera eficiente y acorde con su dinámica, tal es el caso del reciente inventario nacional forestal periódico en cual empleo técnicas de Sensores Remotos y Sistemas de Información Geográfica (Memorias del Inventario Nacional Periódico, SARH, 1994)

Sobre aspectos similares a mediados de 1991 la Secretaría de Agricultura y Recursos Hidráulicos encomendó al Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) la implementación de una herramienta que le permitiera, de manera eficiente, identificar las áreas a nivel nacional con el potencial físico-climático natural para el desarrollo de especies vegetales consideradas estratégicas en cada estado de la república mexicana (Moreno, 1995).

Debido a la magnitud del trabajo y a la escasez de recursos, fue necesario presentar y evaluar varias alternativas de acción eligiéndose como herramienta básica los Sistemas de Información Geográfica debido a sus amplias capacidades de aplicación en la evaluación y administración de los recursos naturales, algunas de estas se observan en los trabajos de Hutachareon, 1988; Howard and Barr, 1991; Van Sickle, 1989; Moeller, 1991 y Campbell *et al.*, 1995.

El trabajo dio inicio en septiembre de 1992 y se terminó en marzo de 1993 y fue desarrollado por un equipo interdisciplinario integrado por investigadores de las tres áreas del INIFAP.

Producto de este trabajo fue la determinación de áreas con potencial productivo para un conjunto de 10 a 15 especies vegetales consideradas estratégicas en cada estado de la república, así como la consecuente información digital empleada en los análisis respectivos, ya que en el tiempo en que se realizaron estos estudios no existía información digital sobre el particular, a excepción de los datos del modelo de elevación digital de INEGI.

Dadas las limitaciones de tiempo y recursos, el trabajo se abordó a través de una metodología simplificada en extremo, la cual consideró información de clima, suelo y topografía como base para la combinación de los elementos físico-climáticos que determinarían la capacidad potencial de un sitio para responder a los factores de desarrollo requeridos por las especies consideradas. Tales requerimientos se establecieron considerando principalmente los resultados de investigación generados por el INIFAP y las experiencias empíricas y practicas de las personas que tenían relación directa con estas especies.

Posteriormente, durante 1994 el Centro Nacional de Investigación Disciplinaria en Conservación y Mejoramiento de Ecosistemas Forestales dependiente del INIFAP retomo estos esfuerzos para mejorar el nivel de resolución de las coberturas de información generadas. Durante este tiempo se corrigieron los errores de digitalización de la información edafológica y su base de datos asociada, se incluyeron nuevas variables a la información de clima y se procesó el

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modelo de elevación digital de INEGI a su máxima resolución (un dato cada 3" de grado). Una descripción detallada de estos trabajos pude ser consultada en Moreno *et al.*, 1995a.

Después de estos primeros trabajos se han continuado desarrollando estudios por diferentes áreas del INIFAP, así por ejemplo se tienen los estudios de potencial productivo para el estado de Guanajuato, los cuales han retomado en gran medida la metodología inicial para aplicarla a una escala de mayor detalle (1:50000) y con un enfoque principalmente agrícola, algunas actividades del proyecto de "Bosque Modelo" en el estado de Chihuahua y el proyecto de mejoramiento y utilización de agostaderos de las zonas áridas y semiáridas de México.

Dadas las condiciones y experiencias actuales del INIFAP se considera que existen dos perspectivas para abordar el conocimiento y evaluación de los recursos naturales en México desde el punto de vista de la investigación. La primera de ellas es realizar estudios de alcance nacional y regional que apoyen en la solución de los grandes problemas nacionales y den elementos para la planeación y toma de decisiones estratégicas para la conservación, manejo y uso sustentable de los recursos naturales. La segunda perspectiva debiera ser orientada a la realización de estudios en áreas específicas de pequeña magnitud que resuelvan problemas puntuales, que aunque se observen a nivel nacional o regional, por sus características particulares requieren un tratamiento específico y de mayor detalle.

Referente al primer enfoque, en términos generales es reducido el número de trabajos que en México existen, ya que las instituciones tradicionalmente han desarrollado estudios con el segundo tipo de orientación, lo que hace necesario realizar investigación para atender y apoyar en la solución de problemas como la perdida de cobertura vegetal, el cambio de uso del suelo, la perdida de productividad en áreas forestales y agropecuarias asociadas a los recursos naturales, los procesos erosivos, los incendios forestales, las plagas y enfermedades de amplia distribución en los bosques y la disminución de la biodiversidad.

Es evidente que para realizar este tipo de trabajos se requiere ampliar la información digital con que cuenta el INIFAP, considerando entre otras capas de información las vías de comunicación, la infraestructura forestal, la cubierta vegetal y la distribución de especies de flora y fauna de importancia económica y ecológica como por ejemplo aquellas consideradas amenazadas o en peligro de extinción. Es también claro que la generación de esta información en medios que permitan su acceso y manejo de manera dinámica, así como su análisis con técnicas y metodologías de simulación en tiempo real es un proceso costoso que implica en cierta forma la obligatoriedad de buscar unir esfuerzos con otras dependencias que se encuentren generando información de este nivel con la finalidad de abatir estos costos y establecer estándares que permitan el uso común de esta información. En este sentido el INIFAP se encuentra colaborando con la Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP) en la implementación de un conjunto de lineamientos de utilidad común en Sistemas de Información Geográfica, así como en proyectos específicos de colaboración con el Servicio Forestal de los Estados Unidos para evaluar combustibles forestales en los estados de Chihuahua y Durango y en el monitoreo de los niveles de contaminantes atmosféricos en los alrededores del Distrito Federal, específicamente en el Parque Nacional "Desierto de los Leones". Similarmente se ha establecido contacto con la Dirección de Recursos Naturales de la SEMARNAP para tener acceso a la información derivada del reciente Inventario Forestal Periódico.

En lo que a la segunda perspectiva se refiere el INIFAP, así como otras instituciones en México han desarrollado un número considerable de estudios sobre evaluación y monitoreo de recursos naturales empleando en ello diversas metodologías, incluyéndose en los últimos años la Percepción Remota a través de imágenes de satélite y los Sistemas de Información Geográfica, sin embargo, es importante señalar el hecho de que aunque estos trabajos resolvieron o ayudaron en la solución de muchos problemas específicos, en la mayoría de los casos no formaron o forman parte de un proyecto con un enfoque sistémico que este orientado a la conjunción de estos resultados con el objeto de resolver un problema de mayor nivel. Tampoco se han desarrollado pensando en que la información que generan o utilizan pueda ser útil y se encuentre en formatos y medios disponibles para otros usuarios que trabajan en las mismas localidades o en áreas con condiciones semejantes. Por tal motivo es recomendable que los trabajos que las instituciones realicen traten de la medida de los posible manejar

estándares en cuanto a la información que generan y mantengan comunicación sobre estos estudios que no obstante se puntuales pueden llegar a se repetitivos incrementando el costo de la solución de los problemas.

Es importante anotar que debido a la dinámica de los procesos que se realizan en los bosques y en general en los ecosistemas naturales, es necesario establecer mecanismos para mantener actualizada la información a mínimo costo y sin perdida de calidad a la par con un mecanismo eficiente de difusión y acceso de la misma. Para lo anterior es recomendable contar con servicios electrónicos de información que operen sobre plataformas de nivel medio y avanzado, es decir, en estaciones de trabajo o minicomputadoras y bajo esquemas de redes, especialmente en estos tiempos en que los volúmenes de información son grandes y la tendencia para su manejo se está orientando a manejadores de bases de datos potentes y con estrategias de bases de datos distribuidas. Los aspectos anteriores están directamente relacionados con una adecuada planeación en el establecimiento de un sistema de información que para el caso de los Sistemas de Información Geográfica, Moreno (1995) sugiere sean tomadas en cuenta la siguientes precauciones.

1. Los Sistemas de Información Geográfica (SIG) son una tecnología cara, no obstante que existe una amplia variedad de productos en el mercado ya que es posible encontrar software de SIG desde menos de $ 1000 US Dólares hasta más de $ 30 000. Muchos de estos programas tienen la capacidad de funcionar en computadoras personales, pero para un buen funcionamiento se requiere que éstas tengan alta capacidad de procesamiento, un buen monitor para gráficos y discos duros de alta capacidad, lo cual implica un costo aproximado entre los $ 2 500 y $ 5 000 US Dólares. Además, dependiendo del volumen de información a manejar y la complejidad de los procesos, se puede requerir como plataforma para el SIG una estación de trabajo operando bajo UNIX, que dependiendo de la configuración, puede costar entre $15,000 y $50,000 US Dólares.
2. El costo de la compra del programa y el equipo de cómputo representan sólo la punta del iceberg, entre el 15% y el 25% del costo total de tener el sistema totalmente operando (Berry, 1989). El costo más grande es la construcción de la base de datos necesaria para operar el sistema. De acuerdo con Antenucci (1991), este costo representa el 50% del costo total de tener el sistema operando. El cuello de botella en la implementación de un SIG es el proceso de entrada de datos, en especial la digitalización de la información cartográfica existente (Frank *et. al.*, 1991). El siguiente costo en orden de magnitud es la capacitación del personal, el cual representa aproximadamente el 25% (Antenucci, 1991). Finalmente, existen una serie de costos ocultos que van apareciendo en el proceso de establecimiento y operación del SIG. Entre ellos: tecnología de apoyo (instalaciones especiales, equipo extra, etc.), cambios operativos e institucionales necesarios para la eficiente operación del sistema.
3. Debido al tiempo necesario para construir la base de datos, no se pueden dar resultados rápidamente, lo cual es esperado por políticos y autoridades. El hecho de no dar resultados rápidamente puede provocar frustración y retiro de apoyo político y económico para los proyectos de SIG.

En complemento a lo anterior y para minimizar las sorpresas y riesgos en la selección y puesta en marcha de un SIG se recomienda:

1) Hacer un inventario detallado de las necesidades del usuario.
2) Hacer una lista detallada de toda la información existente que se le alimentará al sistema indicando cantidad, tipo y calidad de la misma.
3) Hacer una lista detallada de la información que no está disponible y que será necesario recolectar indicando cantidad, tipo y calidad de la misma.

4) Con los tres puntos anteriores preparar un concurso entre vendedores de SIG. Llevar a cabo pruebas de comparación entre ellos.
5) Una vez seleccionado el sistema, obtener del vendedor los requerimientos necesarios para el lugar donde se instalará el SIG. Entre otros: Espacio, temperatura, humedad, energía eléctrica, condiciones del edificio (sin alfombra, ventilación, sin sol, protección contra choques de energía eléctrica y robo, etc.).
6) Hacer previsión en cuanto a tiempo y dinero para la capacitación del personal.
7) Establecer prioridades para la captura de la información.
8) Hacer planes piloto para la aplicación del SIG para tener resultados en poco tiempo y mantener el interés y apoyo económico y político de autoridades y políticos.
9) Establecer tablas de tiempo realistas para la captura, procesamiento, análisis y obtención de resultados. Esto es para no tener falsas expectativas que a l no cumplirse provocan frustración y descontento.
10) Hacer una cuidadosa planeación financiera. La construcción de la base de datos se debe de considerar como una fuerte inversión de capital y debe ser planeada cuidadosamente.
11) Prever los cambios operacionales e institucionales que serán necesarios al introducir el SIG. La introducción de un SIG a una institución altera los flujos de información dentro de la organización, así como la estructura de la misma. Con un SIG no se hacen las mismas cosas de antes y de la misma manera, pero ahora más rápidamente. La información seguirá diferentes rutas dentro de la institución y un SIG es una tecnología que requiere de personal capacitado que debe ser bien pagado y respetado.
12) Se deben hacer previsiones para determinar mecanismos de control y establecimiento de derechos de acceso a la información contenida en el SIG. En los E.E.U.U., han habido problemas legales sobre quien tiene acceso a la información, por ejemplo de ingresos económicos, valor catastral de propiedades, número de hijos, grupo étnico, etc., dado que esta información se puede usar para hacer discriminaciones de diversos tipos sin el conocimiento de los individuos afectados.
13) Llevar un registro "pedigrí" de la información y los procesos empleados en su generación. Esto es particularmente importante cuando se manejan grandes volúmenes de información y muchos procesos de análisis a la misma.
14) Desde el diseño del sistema se deben de prever los mecanismos y subsistemas para hacer la información accesible a usuarios y tomadores de decisiones sin entrenamiento en SIG. El impacto final de un proyecto de SIG depende en gran medida de contar con una interfase amigable que permita hacer uso de la información para apoyar la toma de decisiones (Moreno *et al.*,1995b). Se recomienda seguir una estrategia de base de datos distribuida con el grueso del volumen de información en un servidor UNIX, la cual puede ser accesada en red local por terminales PC. La ventaja de esta estrategia es que facilita el desarrollo de interfaces en PC's en ambiente Windows o con software de simulador de terminales gráficas tal como PC-XWARE.

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Monitoreo Ambiental en Ecosistemas Acuáticos de México

Edmundo Díaz-Pardo, Eugenia López-Löpez y Eduardo Soto-Galera[1]

ABSTRACT.--As occurs in other countries, the surface waters of Mexico support pollution and high nutrient concentrations. Furthermore, its demand has increased but its availability has diminished. In this contribution, we expose the survey that the staff of National School of Biological Sciences(ENCB-IPN) has carried out from 1985 to date, in order to asses some water bodies.

Methods and technics used in the different stages of long and short terms assessment and its relationship with social and economic factors to establish a diagnostic of the ecosystems health are explained. The study case of Lerma river basin is used to set an example of long term assessment and the case of Ignacio Allende Reservoir, in turn, is used to the short term assessment. Besides some results of ecotoxicological studies realized in industrial effluents and in receptors water bodies, both belonging to Lerma basin, are shown.

INTRODUCCION

El siglo XX se ha caracterizado, entre otras cosas, por los grandes avances tecnológicos, mismos que han propiciado el rapido incremento poblacional, urbano, industrial y agrícola. La acción conjunta de todos ellos ha conducido a la contaminación del agua y a la liberación de grandes cantidades de nutrientes; además, por una parte se ha incrementado el consumo de agua, pero por otra se ha reducido su volumen disponible y se ha mermado la capacidad reguladora de la misma. El resultado es la disminución de los valores económico, recreacional y estético del agua, así como de la cantidad y calidad del habitat para la biota acuática, propiciando, incluso, la extinción de muchas especies.

Ha sido indispensable la implementación de planes de manejo que contemplen a los ecosistemas acuáticos de forma integral, con el fín de darles usos multiples, pero también se ha tenido que recurrir a medidas normativas cada vez más estrictas, que prevengan mayores daños a estos ecosistemas, y en los casos más severos se ha tenido la necesidad de acudir a planes de restauración ecológica. Por tanto, ha sido imprescindible elaborar métodos de seguimiento o de monitoreo que permitan detectar el grado de impacto, así como los avances en los planes de manejo o restauración.

Por esta razón, mi intervención en este foro tiene como objetivo presentar el modelo de estudio que los investigadores de la Escuela Nacional de Ciencias Biológicas (ENCB-IPN), han desarrollado para la evaluación del impacto ambiental y en el monitoreo de algunos ecosistemas epicontinentales mexicanos.

Muchos autores han resaltado la importancia que en los estudios ambientales básicos y en los de monitoreo tiene el conocimiento de la diversidad de la biota, los valores ambientales en que se desarrolla y el papel que juegan en esos sistemas naturales, como paso inicial para determinar la cantidad y el tipo de cambio que las actividades humanas provocaran y los posibles efectos que a corto y largo plazo tendrán los ecosistemas.

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En este contexto, la bióta en general y los peces en particular tienen un valor especial, porque muchas especies son altamente susceptibles a los cambios ambientales y manifiestan sus efectos en formas muy distintas. La evaluación de la riqueza específica es probablemente el mejor indicador de la degradación ambiental, pero los peces la manifiestan, también, en abundancia y restricción de su distribución geográfica, con cambios en la estructura de una comunidad (las redes tróficas tienden a simplificarse), porque acumulan tóxicos en sus tejidos, o en casos drásticos porque desaparecen local o totalmente. Este tipo de estudios tienen la posibilidad de llevarse a cabo mediante la comparación en el tiempo o en el espacio y el resultado final es el establecimiento del diagnóstico de las condiciones de salud de un ecosistema, como base para la propuesta de medidas preventivas y/o correctivas.

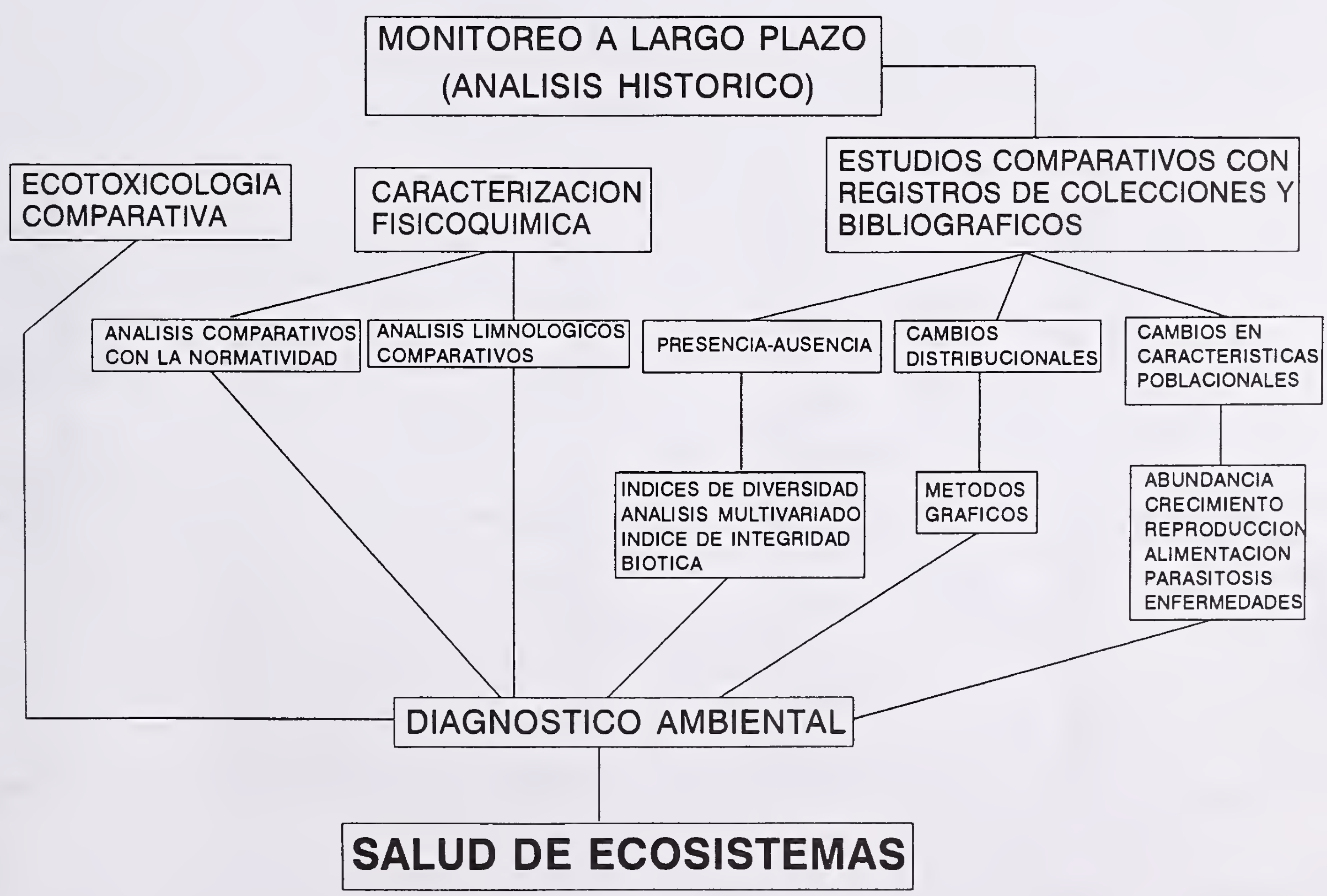
METODOS DE MONITOREO

El modelo general seguido por nuestro grupo de trabajo contempla el conocimiento de la porción abiótica (calidad del agua) y de los componentes vivos del ecosistema, así como de los factores socioeconómicos causales que permiten establecer un diagnóstico ambiental. Dado que los métodos y técnicas empleadas se han estandarizado, este modelo holístico se ha usado en el seguimiento de distintos cuerpos de agua epicontinentales de México. Dependiendo de la naturaleza del problema a resolver se ha hecho a corto plazo (< 5 años) y a largo plazo (> 5 años) y también, en diferentes niveles de organización: organismo, población, comunidad y en el ecosistema como un todo.

En cualquiera de los dos tipos de monitoreo, el trabajo de campo se basa en los métodos limnológicos y de la biología pesquera convencionales, mientras que en el laboratorio las determinaciones fisicoquímicas derivan de las técnicas espectrofotométricas Hach-2000.

MONITOREO A LARGO PLAZO

Dentro del monitoreo a largo plazo (Fig. 1), la utilización de información procedente de colecciones científicas, es particularmente significativa, ya que la comparación a través del tiempo de los patrones de



1. Modelo de monitoreo a largo plazo.

distribución específica, características poblacionales y de la estructura de las comunidades, permiten establecer un buen diagnóstico de la salud de los ecosistemas.

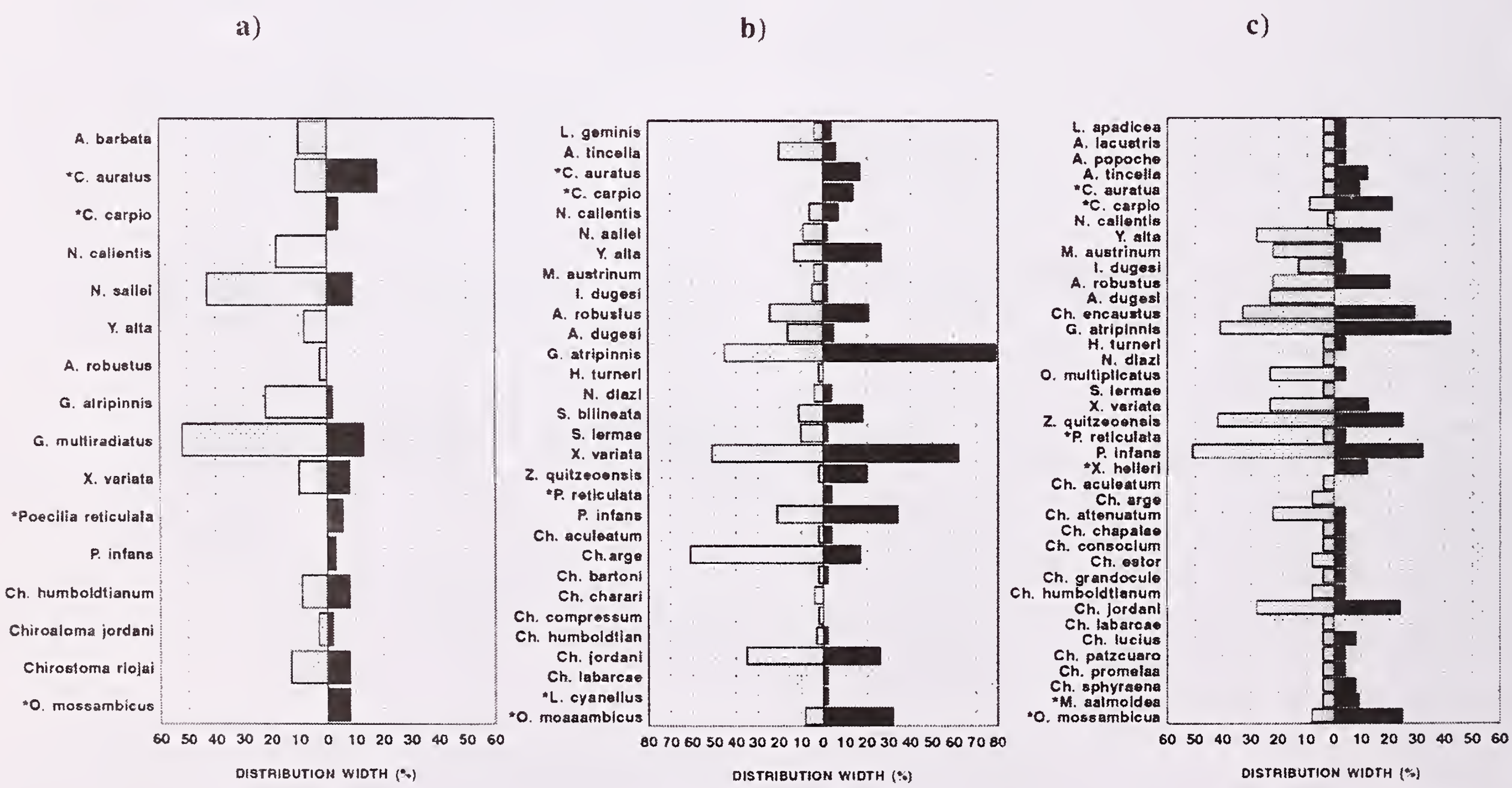
En este sentido, el análisis contempla establecer por métodos gráficos los cambios en amplitud de la distribución de las especies. El abatimiento en el tamaño poblacional por medio de la determinación de cambios en la abundancia, crecimiento (edad, relación peso-talla, factor de condición)), reproducción (indice gonadosomático, fecundidad relativa, temporada de reproducción y reclutamiento reproductivo), dieta y hábitos alimentarios, así como en la incidencia de enfermedades y parasitósis. También, establecer la posible pérdida de la capacidad del ambiente para soportar ecosistemas altamente organizados, mediante la utilización de indices de diversidad, métodos multivariados (empleando matrices de abundancia por especie) e indices de integridad biótica.

En cuanto a la caracterización fisicoquímica del agua, se pretende diagnosticar los cambios en su calidad, para distinguir la evolución que han sufrido los cuerpos de agua en el tiempo. Así como para conocer la relación que guarda dicha calidad con la normatividad vigente.

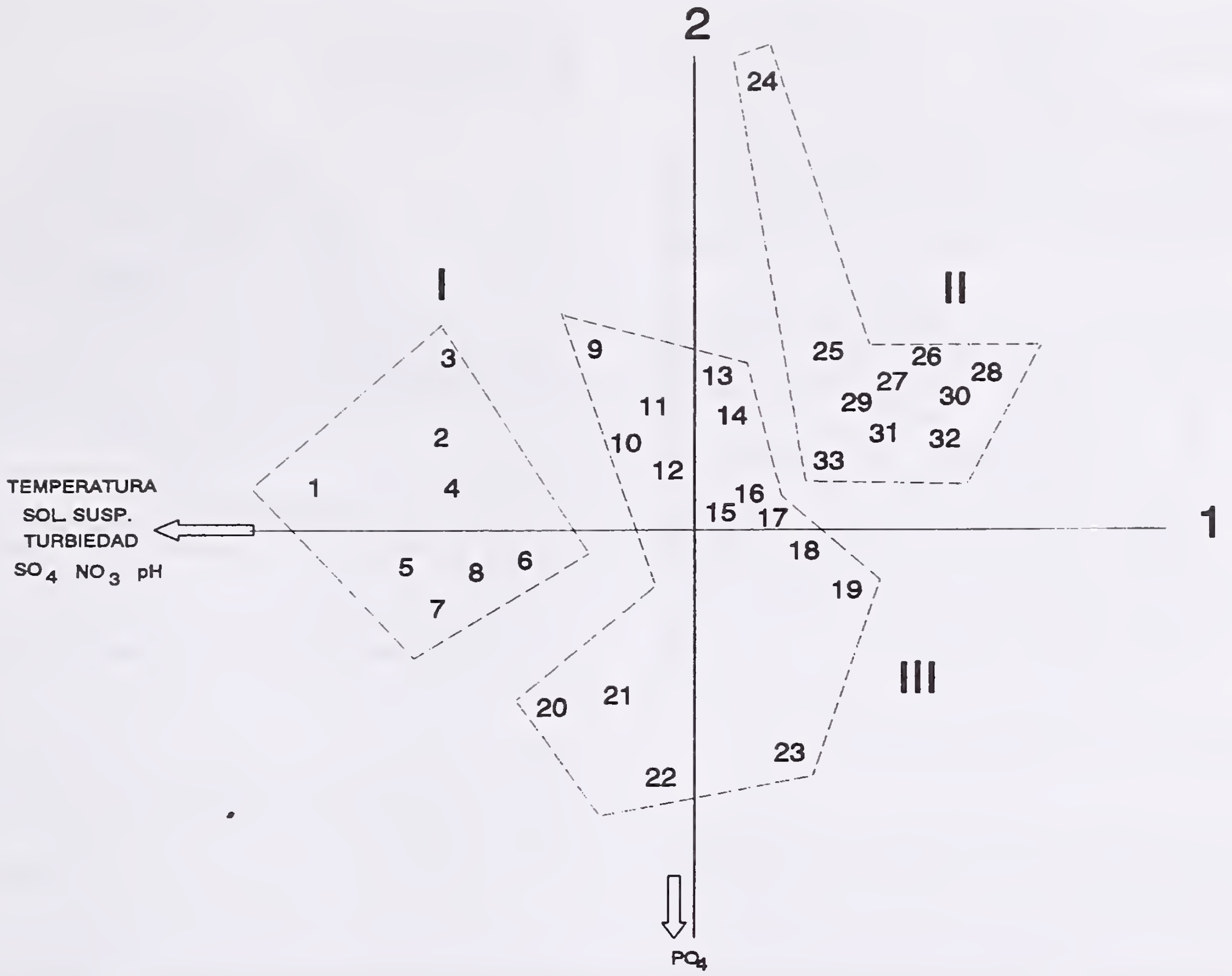
De manera resumida presento como ejemplo del monitoreo a largo plazo el estudio realizado en la cuenca del río Lerma, entre 1985 y 1993 (Soto-Galera, 1989; López-López y Díaz-Pardo, 1991; Diaz-Pardo et al 1993) que se inicio con el acopio de registros citados en la literatura y los provenientes de las Colecciones Cientificas de Peces (que en conjunto llamaremos antecedentes) y a partir de los cuales se ubicaron 120 localidades de muestreo, cada una de ellas fue visitada en cuando menos dos estaciones del año (estiaje y lluvias)

Los valores del análisis fisicoquímico y la similitud ictiofaunística fueron tratados por métodos multivariados de agrupación, lo que permitió la detección de tres ecoregiones en esa cuenca, mismas que fueron analizadas de forma independiente:

a) Por métodos gráficos se contrastó la presencia-ausencia de peces entre los antecedentes y el resultado del muestreo 1985-1993, lo que permitió conocer los cambios en la diversidad y en la amplitud de distribución (Fig. 2).



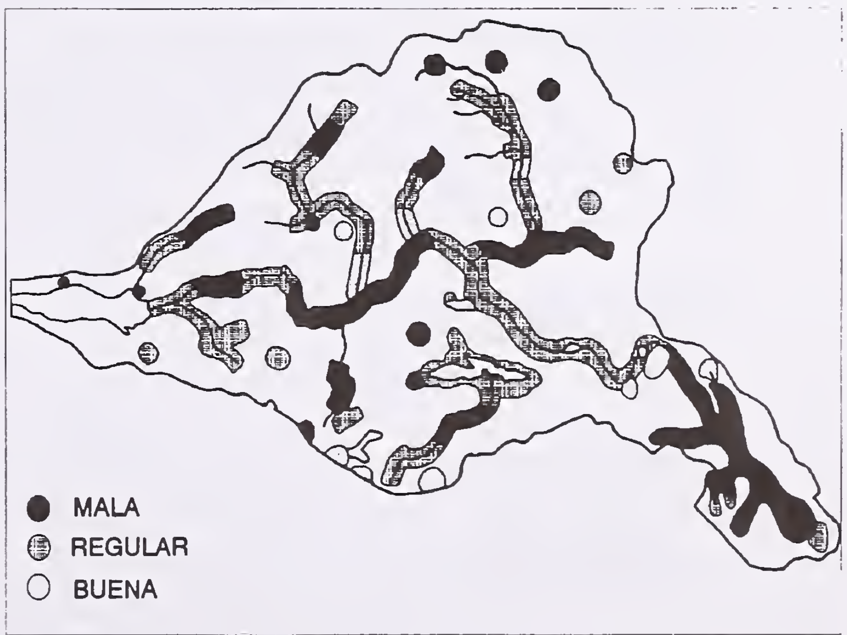
2. Cambios distribucionales en la ictiofauna del río Lerma. a) Alto Lerma, b) Medio Lerma, c) Bajo Lerma. Las barras de color gris representan los antecedentes y las negras los resultados obtenidos durante el periodo1985-1993.



3. **Ordenación de especies (ACP) de acuerdo con la amplitud de tolerancia a los factores ambientales. 1 *Goodea atripinnis*, 2 *Xenotoca variata*, 3 *Chirostoma jordani*, 4 *Poeciliopsis infans*, 5 *Oreochromis mossambicus*, 6 *Yuriria alta*, 7 *Carassius auratus*, 8 *Cyprinus carpio*, 9 *Alloophorus robustus*, 10 *Chirostoma riojai*, 11 *Skiffia bilineata*, 12 *Allotoca dugesi*, 13 *Chirostoma arge*, 14 *Chirostoma aculeatum*, 15 *Notropis sallei*, 16 *Chapalichthys encaustus*, 17 *Xiphophorus helleri*, 18 *Chirostoma bartoni*, 19 *Notropis calientis*, 20 *Algansea tincella*, 21 *Girardinichthys multiradiatus*, 22 *Chirostoma humboldtianum*, 23 *Moxostoma austrinum*, 24 *Neophorus diazi*, 25 *Chirostoma labarcae*, 26 *Lepomis cyanellus*, 27 *Skiffia lermae*, 28 *Ollentodon multipunctatus*, 29 *Ictalurus dugesi*, 30 *Lampetra sp*, 31 *Zoogonecticus quitzeoensis*, 32 *Micropterus salmoides*, 33 *Poecilia reticulata*.**

b) Se empleó el análisis multivariado de ordenación, con la matriz de factores ambientales por localidad, con el fin de ubicar los sitios con diferente calidad de agua.

Por otro lado se calculó la amplitud de tolerancia de cada especie a los distintos factores ambientales que prevalecen en toda la cuenca, información que fue empleada en un análisis multivariado de ordenación de especies, con lo que se reconocieron tres grupos: sensibles, medianamente tolerantes y tolerantes. Esta información se conjugó con la ordenación de sitios de acuerdo con la calidad del agua, para establecer la salud de los sistema acuáticos de la cuenca (Fig. 4). Como consecuencia 9 especies se jerarquizaron de acuerdo con los criterios propuestos por la American Fisheries Society para las especies en riesgo (Soto-Galera et al 1991).



4. **Condiciones de salud de las corrientes tributarias y principal de la cuenca del río Lerma.**

Estos resultados nos permitieron participar en la elaboración de la NORMA OFICIAL MEXICANA QUE DETERMINA LAS ESPECIES DE FLORA Y FAUNA EN PELIGRO DE EXTINCION, AMENAZADAS, RARAS Y LAS SUJETAS A PROTECCION ESPECIAL (NOM-059-ECOL. 1994), en la cual quedaron incluidas 15 especies.

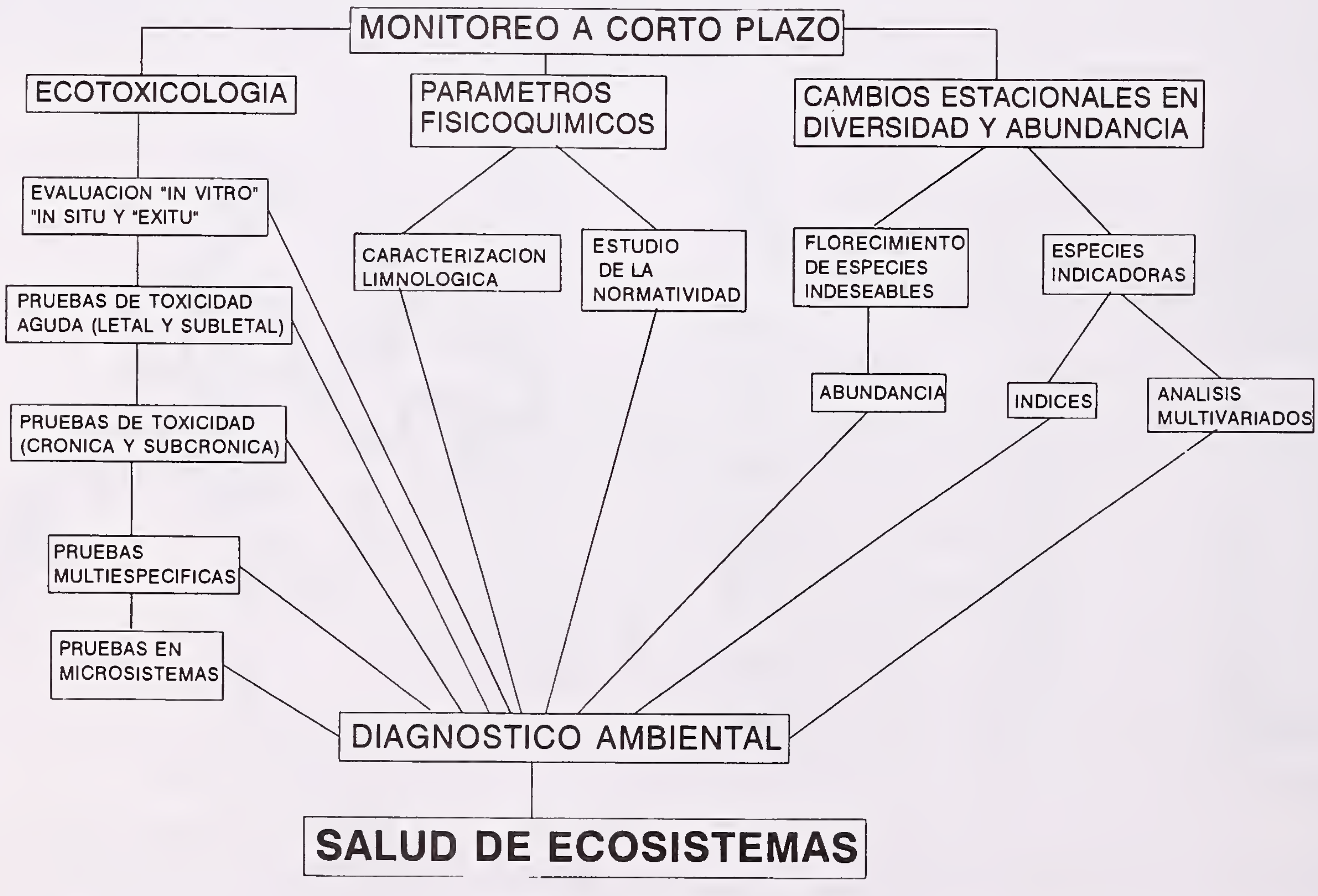
La búsqueda de las causas del impacto ambiental sobre la calidad del agua y los peces se realizó estableciendo el papel de algunos factores socioeconómicos, principalmente los relacionados con el uso del suelo. La integración de los resultados antes mencionados dio como conclusión el estado de salud de las diferentes porciones de las corrientes tributarias y principal de la cuenca del río Lerma (Soto-Galera *et al.*, en prensa) (Fig. 5).

5. Usos del suelo en la cuenca del río Lerma.

MONITOREO A CORTO PLAZO

Durante el desarrollo del estudio antes descrito, se ejecutaron monitoreos a corto plazo en aquellos sitios que mostraron cambios más acentuados y rápidos, tal es caso del Embalse Ignacio Allende ubicado en el curso del río de la Laja en Guanajuato, perteneciente a la misma cuenca del Lerma (Díaz-Pardo *et al.*, 1991).

En el monitoreo a corto plazo (Fig. 6), se realiza una caracterización de los sistemas en función de los cambios estacionales, según el regimen climático en



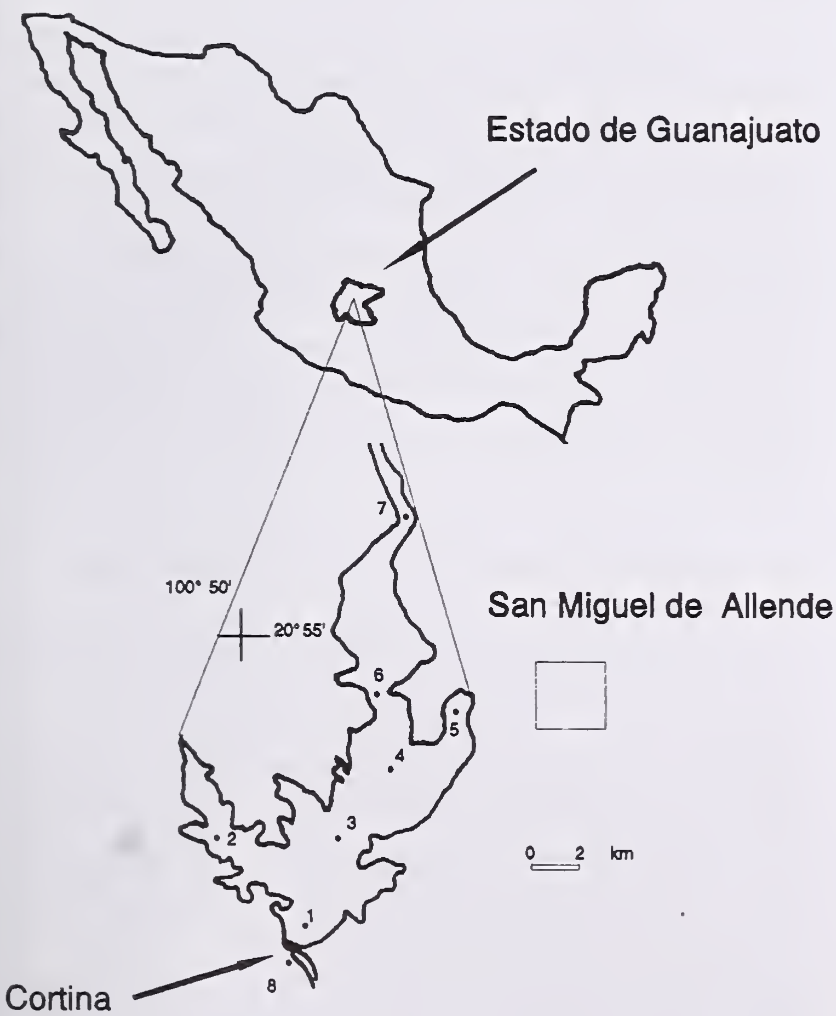
6. Modelo de monitoreo a corto plazo.

el que se encuentre, y detectar su efecto en los factores físico-químicos y su relación con la diversidad y abundancia de las comunidades, mediante el uso de índices y métodos multivariados.

Esta fase cumple con el cometido de detectar florecimientos planctónicos, los factores causales que los determinaron y con el empleo de índices y métodos multivariados identificar especies indicadoras de ciertas condiciones ambientales.

Para este embalse, existian como antecedentes los monitoreos de la Comisión Nacional del Agua durante 1985. En nuestro estudio (1990-1991) se ubicaron sitios de muestreo dentro del embalse, en el tributario y en el efluente (Fig. 7), que fueron visitados mensualmente durante un ciclo anual, con el fín de realizar la caracterización limnológica completa, incluyendo la parte ambiental y las comunidades del plancton y del necton.

Mediante métodos de agrupación se establecieron las similitudes entre los sitios, para cada mes de estudio, lo que permitió conocer el efecto de la corriente afluente y del manejo de las compuertas, en la calidad del agua y en las comunidades planctónicas e ícticas.



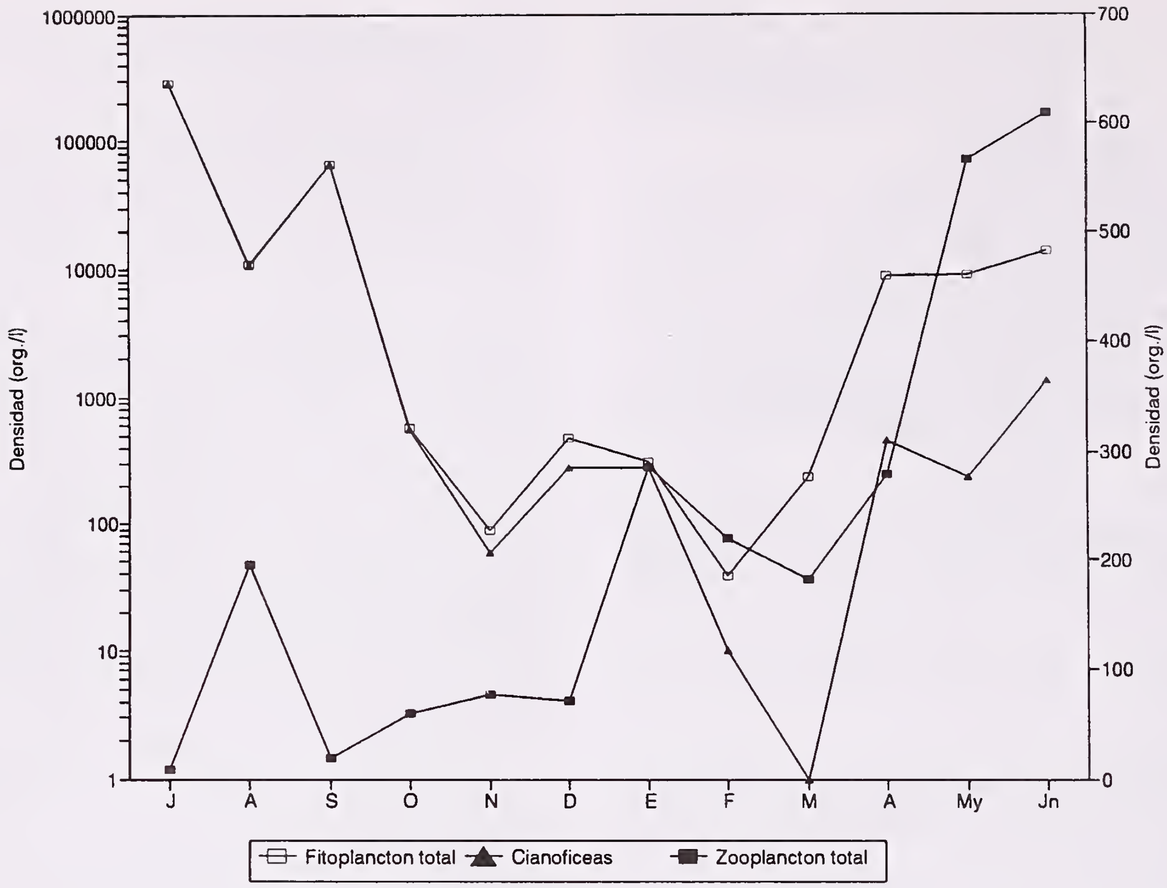
7. **Ubicación de sitios de estudio en el embalse Ignacio Allende, Guanajuato, México.**

Con el fín de evaluar la carga de fósforo y el estado trófico del ecosistema, se aplicó el modelo de balance de masas, el cual muestra que el embalse Begonias alcanza condiciones de hipereutrofía. El mismo modelo aplicado con los valores de 1985 y comparandolo con los resultados de 1990 permite conocer la tasa de ganacia en la carga de fósforo (Fig. 8), así como la velocidad con la que el sistema evoluciona a condiciones de eutrofia avanzada (López-López y Soto-Galera 1993). Esta información lleva a sugerir los niveles máximos permisibles de carga de fósforo que soporta el embalse en estudio, y así evitar un incremento desmesurado en el proceso de eutroficación. Los resultados podrían ser de interés en las acciones regulatorias de la región de estudio.

En cuanto al análisis de las comunidades, se realizaron análisis de ordenación por correspondencias canónicas, para detectar las especies típicas de cada uno de los momentos por los que atraviesa el sistema; así también, se detectó que los florecimientos de cianoficeas son coincidentes con las bajas densidades zooplanctónicas (Fig. 9) y las mortandades masivas de peces, todo ello evidenció las malas condiciones de salud en el ecosistema (López-López *et al.* en prensa).

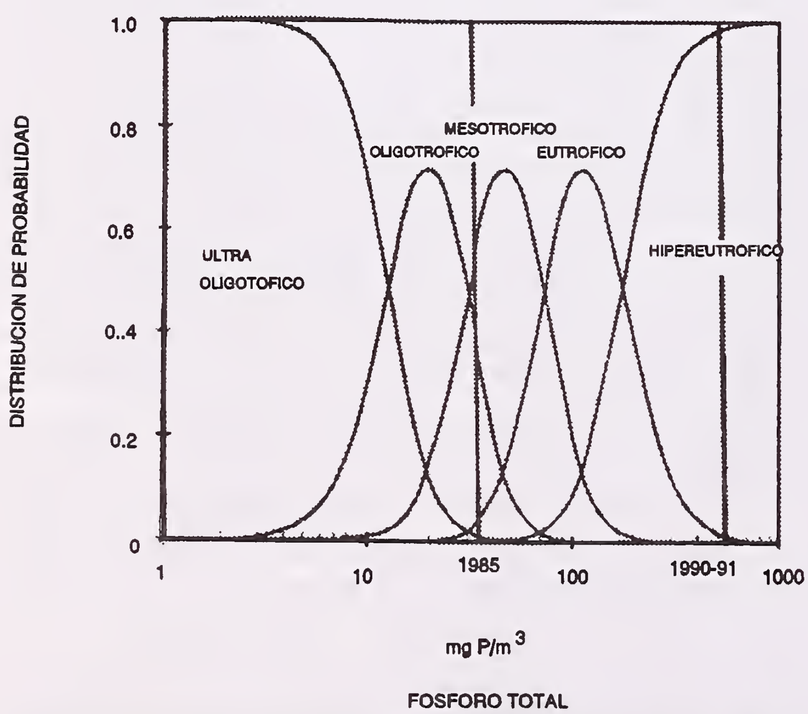
También, por solicitud directa de algunas empresas se han realizado análisis ecotoxicológicos de efluentes industriales que descargan en el rio Lerma. Aqui me quiero detener para explicar algunos antecedentes sobre este tipo de análisis. Actualmente el único método estandarizado de tipo biológico que se aplica en México implica el uso de *Daphnia magna*, tanto en pruebas de toxicidad agúda, como crónicas y subcrónicas, en la aplicación de aguas provenientes de efluentes, efluentes tratados y cuerpos receptores.

La ENCB-IPN, después de muchos años de trabajo con *D. magna* ha desarrollado la producción de lotes de órganismos controlados para su aplicación en pruebas toxicológicas, como la realizada para una industria farmaceutica cuya matriz en EUA le demandó a su filial mexicana pruebas de sus efluentes (a pesar de que la legislación mexicana no lo exigía). Para evaluar el nivel de calidad de nuestros estudios se hicieron pruebas comparativas con determinaciones realizadas en EUA y los resultados fueron semejantes y apegados a lo previsto. Una vez que el método y la calidad de las pruebas fueron



8. Modelo probabilístico del estado trófico en el embalse Ignacio Allende, Guanajuato, México.

validados, otro factor ha considerar fue el costo, que obviamente favorecio a las pruebas ejecutadas en la ENCB-IPN. Estas experiencias condujeron a la participación de nuestros investigadores en los trabajos para elaborar la NORMA MEXICANA correspondiente.



9. Densidades zooplanctónicas y fitoplanctónicas en el embalse Ignacio Allende.

La evaluación toxicológica a nivel de microcosmos y mesocosmos de diferentes xenobioticos, como hidrocarburos, insecticidas, detergentes y algunos metales pesados se ha efectuado comparativamente entre cuerpos lacustres con buenas condiciones de calidad de agua con la de otros muy alterados, como es el caso de los embalses Villa Victoria e Ignacio Ramírez, respectivamente. En estos casos se emplearon indicadores bioquímicos como la AChE y lipoperoxidación en *Moina macrocopa* y *Limnnudrilus hoffmeisteri* (Martínez-Tabche et al., in press a, b)

FACTORES SOCIOECONOMICOS

La búsqueda de las posibles causas de impacto sobre los ecosistemas acuáticos consiste en la recopilación de información relacionada con las actividades socioeconómicas de la región en estudio, mediante el empleo de información cartográfica y la obtenida de censos poblacionales, económicos e industriales, y por medio del uso de mapas y métodos de ordenación se establece la posible relación entre las diferentes actividades humanas y la salud de los ecosistemas acuáticos (Fig. 10), como se mencionó en el ejemplo del monitoreo a largo plazo (Soto-Galera *et al.* en prensa).

10. Modelo para el análisis de los factores focioeconómicos.

CONCLUSIONES

Como se puede apreciar, el modelo general de estudio que hemos venido siguiendo ha mostrado sus bondades, los métodos de campo y de laboratorio empleados son accesibles a cualquier otro grupo de trabajo y recomendados por diferentes agencias nacionales e internacionales que norman la calidad ambiental; los análisis estadísticos son relativamente simples, requieren de equipos computacionales menores y han sido probados en ambientes templados y tropicales; la información requerida para conocer la incidencia de los factores socioeconómicos en problemas ambientales es, también, de facil acceso a todo tipo de público . Consideramos que el modelo puede ser seguido por otros investigadores, de tal forma que los resultados puedan ser comparables, lo que contribuira a que el conocimiento, hasta hoy insuficiente y fragmentado de los ecosistemas lénticos de México aumente y permita integrar con eficiencia estrategias de conservación y manejo racional del agua.

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Monitoreo en Reservorios de México

López-Hernández Martín[1] en Guzmán-Arroyo Manue[2]

Abstract-With previous intensive sampling work of several years in the field, two monitoring programs of mexican reservoirs, including a basic ecological frame of one of them, are presented. The dynamics of water temperature and dissolved oxygen concentrations along water column is considered important on the behavior of the reservoir. The social and economic problems caused by dams, can be solved with appropiate sampling program of abiotic and biotic aspects and training on management of fisheries.

INTRODUCCIÓN

A lo largo de su territorio México presenta diversidad climática, fisiográfica, así como diferentes tipos de subsuelos, que en conjunto causa entre otras cosas, amplia desigualdad en la distribución de los volúmenes de agua, por lo que se puede encontrar zonas que disponen de grandes caudales, así como otras en que éstos no son significativos (Luna, 1993); lo anterior proporciona un panorama hidrológico dulceacuícola muy variado y numeroso. Se estima que en nuestro país escurren un total de 4.1×10^{11} metros cúbicos de agua en promedio anual, siendo los ríos y las presas hidroeléctrica o de riego, los principales cuerpos acuáticos.

Las condiciones de fisiografía y clima, así como el constante crecimiento urbano y su respectiva demanda múltiple del recurso, ha orillado a que en México se implementen obras hidráulicas para la utilización más eficiente del agua transportada por los ríos, dando como resultado el incremento notable en el número de presas, que hasta el año 1980 se tenían registradas 1,264 presas (Acosta, 1993) y para 1990 se tiene estimado un total de 1,365; Arredondo y Flores (1992) consideran que en 1988 el área total de agus superficiales era de aproximadamente 1´280,000 has. de agua, de las cuáles el 50% se encontraba en presas, no obstante no hay un censo lo suficientemente exacto en la disponibilidad de aguas superficiales, ya que muchos sistemas acuáticos presentan marcadas variaciones en área y volúmen; lo cierto es que los reservorios ocupan ya un elevado porcentaje de esa disponibilidad de agua superficial, ya que en los últimos 10 años se han incrementado sustancialmente la construcción de presas mayores de 5,000 has, como "El Caracol" (Guerrero), "Cerro de Oro" (Oaxaca), "Zimapan" (Hidalgo), "Aguamilpa" (Nayarit).

La actual cantidad de reservorios de México refuerza la importancia que tiene el dirigir los estudios limnológicos tanto a los reservorios como a los ríos que las alimentan. Así mismo en los reservorios se ha incrementado notablemente los niveles de impacto ambiental sobre los sistemas acuáticos, preferentemente de la calidad del agua, así como la alta carga de material alóctono que repercute en el envejecimiento acelerado y por tanto reducción en su tiempo de vida. Muchos de esos impactos no han sido aún registrados y cuantificados, debido entre otras cosas a la carencia de información limnológica y biológica que permitan inferir sobre el grado de cambio entre las condiciones originales con las actuales. No debe olvidarse que el hombre es un componente principal de los ecosistemas dulceacuícolas y que su efecto sobre éstos incrementará hasta que el crecimiento en su población y urbanización no se haya estabilizado (Jorgensen, 1980).

PROBLEMATICA DE LA INVESTIGACION LIMNOLOGICA EN MEXICO

Los pueblos prehispánicos de México (aztecas, xochimilcas, texcocanos, purépechas), hacían uso adecuado y con conocimiento de los lagos, en cuanto

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a sus recursos biológicos y algunas de sus características hidrológicas (Deevey, 1957); con la llegada de los conquistadores y el establecimiento de las ciudades españolas mucho de ese conocimiento se fué perdiendo así como algunos de sus sistemas acuáticos que fueron constantemente desecados, como el caso del gran lago de tenochtitlan que en la actualidad está reducido a los canales de Xochimilco, al sur de la ciudad de México; actualmente se hacen estudios de recuperación ecológica del lago de Xochimilco, con fuerte participación conjunta de gobierno, universidades y comunidad (Canabal, 1991).

Los primeros estudios de tipo limnológico se remontan al período 1941-1945 en los lagos naturales de los estados de Jalisco (Chapala) y Michoacán (Pátzcuaro, Cuitzeo, Zirahuén), los primeros años con cierta constancia, que se fué dispersando posteriormente; tuvieron que pasar varias décadas (1971-1974) para que se retomaran los estudios limnológicos en nuestro país. En los últimas 20 años la actividad limmnológica ha considerado a otros sistemas dulceacuícolas como los lagos cráter de los estados de Puebla-Tlaxcala y Estado de México, así como lagos de diferente orígen en Morelos, Veracruz y Tabasco. El estudio en ríos está poco atendido, restringido en la mayoría de los casos a reportes hidrológicos originados en estaciones hidrométricas de instituciones gubernamentales como la Comisión Nacional del Agua y la Comisión Federal de Electricidad.

La investigación limnológica de la mayoría de nuestros sistemas dulceacuícolas se encuentra con bastantes incógnitas, como son la dinámica espacio-temporal de sus diferentes componentes fisicoquímicos en columna de agua, la composición micro y macrobiológica, así como las interelaciones entre los componentes bióticos y abióticos y por ende su reflejo en la productividad primaria y secundaria de esos sistemas; parte de la problemática también surge de la dispersión a lo largo del país de los grupos de trabajo avocados a la limnología, tanto de las dependencias gubernamentales como universidades públicas y privadas; cada grupo investiga en diferentes programas y objetivos de trabajo, así como con criterios y metodologías que con frecuencia no coinciden del todo con los demás.

Otro hecho común es la duplicidad o multiplicidad de estudios sobre un mismo sistema acuático por diferentes grupos de trabajo y que independientemente llegan a sus respectivas conclusiones, las cuáles en el mejor de los casos llegan a publicarse, pero en el caso de las dependencias gubernamentales la información por lo general queda integrada en informes técnicos sin la debida difusión.

Es importante la interacción de grupos de trabajo a nivel interinstitucional e interdisciplinario que permita el flujo de información así como la posibilidad de intercambio de experiencias, en especial sobre las metodologías de trabajo aplicadas para los diferentes sistemas en que se ha trabajado. Es en este punto donde se requiere especial atención ya que es necesario llegar a una uniformidad o estandarización metodológica, aplicable por cualquier grupo de trabajo.

Otro punto a considerar es la cantidad y calidad de la infraestructura para los estudios limnológicos, ya que es diferencial la disponibilidad de la misma entre las distintas universidades y dependencias gubernamentales, como reflejo de sus condiciones presupuestales particulares. Posiblemente parte de esas diferencias en infraestructura sean debidas a que no hay una base sobre la que se apoyen los criterios para la decisión en la adquisición de equipo, reactivos y material de consumo. Por otro lado se debe considerar las funciones básicas de las diferentes escuelas o facultades con respecto a los centros o institutos de investigación en el caso de las universidades, así como de las dependencias gubernamentales; en las universidades la investigación recae principalmente en los centros e institutos y en menor mediad en escuelas y facultades por ser en éstas la docencia el fin primordial.

ENFOQUE DE LA INVESTIGACION EN RESERVORIOS

Considerando que la mayor parte del esfuerzo en investigación limnológica se ha practicado en lagos, el laboratorio de Limnología del Instituto de Ciencias del Mar y Limnología de la UNAM, decidió dirigir sus investigaciones en reservorios (presas) y sistemas de corriente, por considerar que era indispensable generar conocimiento limnológico en estos sistemas que presentan características propias y algunas compartidas con las de los lagos, así como el estar más en dependencia directa con la actividad humana y por lo tanto el factor tiempo de evolución con efectos mas a corto plazo.

Se ha pretendido siempre que los estudios a realizar en reservorios abarque tanto a los componentes bióticos como a los abióticos de cada sistema acuático; también se programa una primera fase de trabajo intensivo para 1-3 años, de la cuál parte la segunda fase (5 o 10 años después) en la que se monitorea el sistema, con el fin tener un patrón de comparación en función al tiempo. Así mismo, durante y al final del proyecto se hacen sugerencias a autoridades y usuarios sobre el manejo racional del sistema y sus recursos, con base a sus condiciones limnológicas particulares.

METODOLOGIA DE TRABAJO

A diferencia de los lagos naturales que han tenido suficiente tiempo para madurar y evolucionar, los reservorios por ser sistemas artificiales y geológicamente recientes, es necesario iniciar la obtención del conocimiento ambiental interno y externo del agua, así como la composición y dinámica de sus componentes biológicos. Thornton (1990) considera que el estudio limnológico de los reservorios es similar al aplicado en lagos, diferiendo posiblemente en el tipo de respuesta de cada sistema, aunque en ambos, se presentan los procesos de mezcla interna, intercambio gaseoso en la interface agua-aire, reacciones redox, suministro de nutrientes, interacciones presa-predador, producción primaria y respiración de la comunidad; así mismo, Wetzel (1990) hace énfasis en la importancia del entendimiento tanto de las diferencias estructurales como de las similitudes funcionales entre estos sistemas, enfatizando que el entendimiento de las diferencias estructurales es lo más importante para llegar al uso y manejo efectivo de los recursos hídricos retenidos.

Siendo los reservorios sistemas híbridos en contínua interacción con el cauce principal, el estudio de estos sistemas acuáticos debe ser interdisciplinario e interactivo en el que participan aspectos de ingeniería hidráulica, hidrológica e hidrodinámica, así como aspectos fisicoquímicos y biológicos, sin olvidar sus diversas interelaciones ecológicas; finalmente debe considerarse también el seguimiento socioeconómico y de la producción alimentaria a través de la actividad pesquera que llegue a establecerse en el embalse.

En México los reservorios han sido cuestionados en relación al balance beneficio-perjuicio en las comunidades ribereñas y regionales, ya que en el caso de las primeras, en la mayoría de los casos son afectados al desplazarlos a otros sitio cuando se inundan sus terrenos, así como por el cambio de actividad primaria, ya que de agricultores de temporal deben cambiar a pescadores, con todos los problemas inherentes al desconocimiento de las tareas de esta nueva actividad; es también frecuente que al tratar de establecer alguna actividad pesquera, se obtengan altas mortandes de peces o bien que los organismos alcancen pequeñas tallas y pesos, con poca demanda en el mercado.

Con el adecuado estudio limnológico y de pesquerías del sistema, se puede llegar al planteamiento de estrategias para resolver los principales problemas relacionados al desconocimiento de la dinámica fisicoquímica del agua y la composición biótica. Como ejemplo, se citará brevemente los trabajos desarrollados en la Presa Yosocuta (Oaxaca), que fueron encaminados a resolver el problema de frecuentes mortandades masivas de peces que habían sido introducidos al reservorio para establecer la actividad pesquera y acuacultural, sin el respectivo éxito.

En 1971 se realizaron estudios de prospección a lo largo de la presa con el fin de establecer la red de estaciones de muestreo, así como explorar la factibilidad del cultivo comercial de peces. Con esta base se estableció un programa de trabajo contínuo a lo largo de tres años, en los que se cubrieron diferentes metas:

a) Ciclo marzo 1972-marzo 1973. Determinación de los ciclos anuales en condiciones naturales de los parámetros físicos, químicos y biológicos limitantes del aprovechamiento piscícola. Se realizaron muestreos semanales en 10 estaciones de trabajo distribuídas a lo largo del embalse, con el fin de conocer la dinámica de los principales parámetros fisicoquímicos del agua, en especial la dinámica del oxígeno disuelto y temperatura en la columna de agua (Figura 1)
b) Ciclo marzo 1973-marzo 1974. Aplicación del conocimiento general de la dinámica del embalse en la corrección de factores ecológicos adversos al desarrollo de los peces y en base a ello instalación de la pesqueríacon un policultivo de 3 especies de peces de importancia comercial: *Tilapia nilotica* (tilapia), *Micropterus salmoides* (lobina negra), *Cyprinus carpio* (carpa). Se diagnosticó la dinámica de las relaciones biológicas y ambientales del sistema hasta

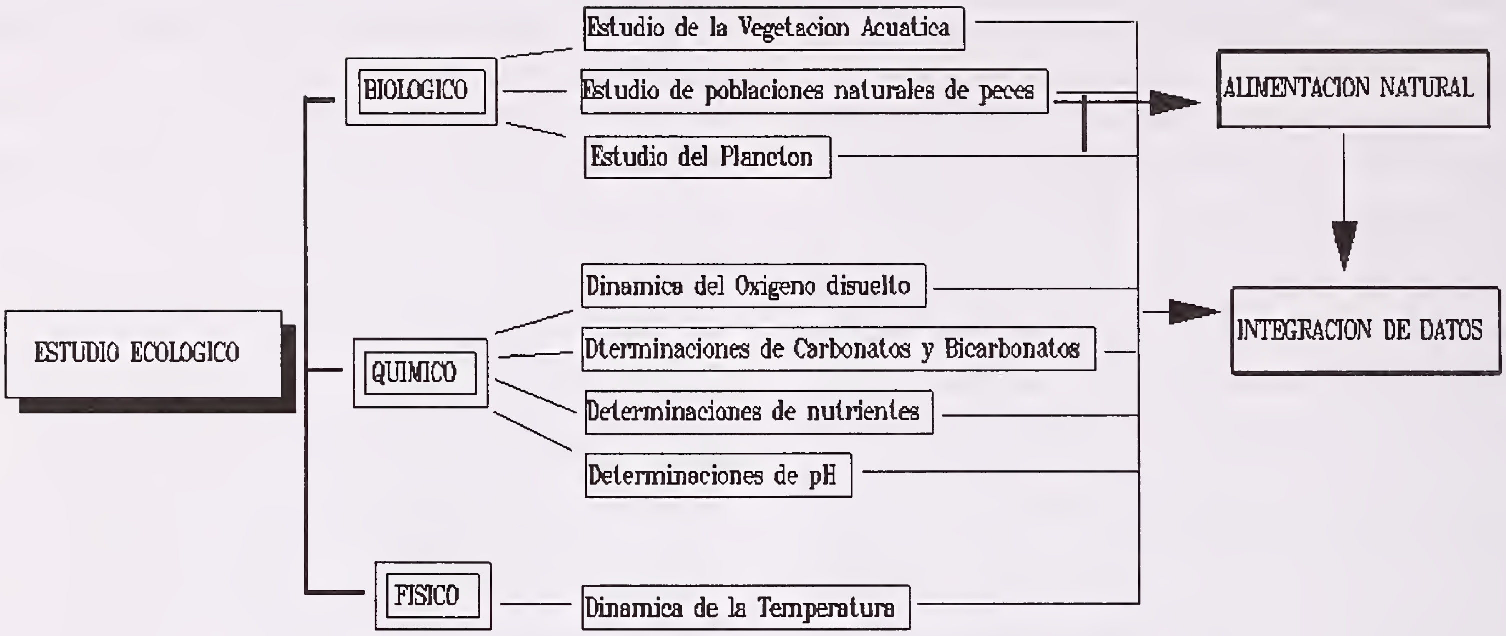


Figura 1. Programa general del estudio ecológico de la Presa Yosocuta.

obtener el cuadro ecológico básico de la presa en el que se esquematizan las diferentes interelaciones bióticas y abióticas (Figura 2); así mismo se recomendaron cambios en la administración del manejo de compuertas, ya que se detectó que su manejo inadecuado era uno de los principales factores adversos para el establecimiento de las comunidades de peces.

c) Ciclo marzo 1974-marzo 1975. Reporte de los registros del primer ciclo de capturas y su evaluación económica, los registros de control de los principales parámetros ecológicos relacionados con el desarrollo

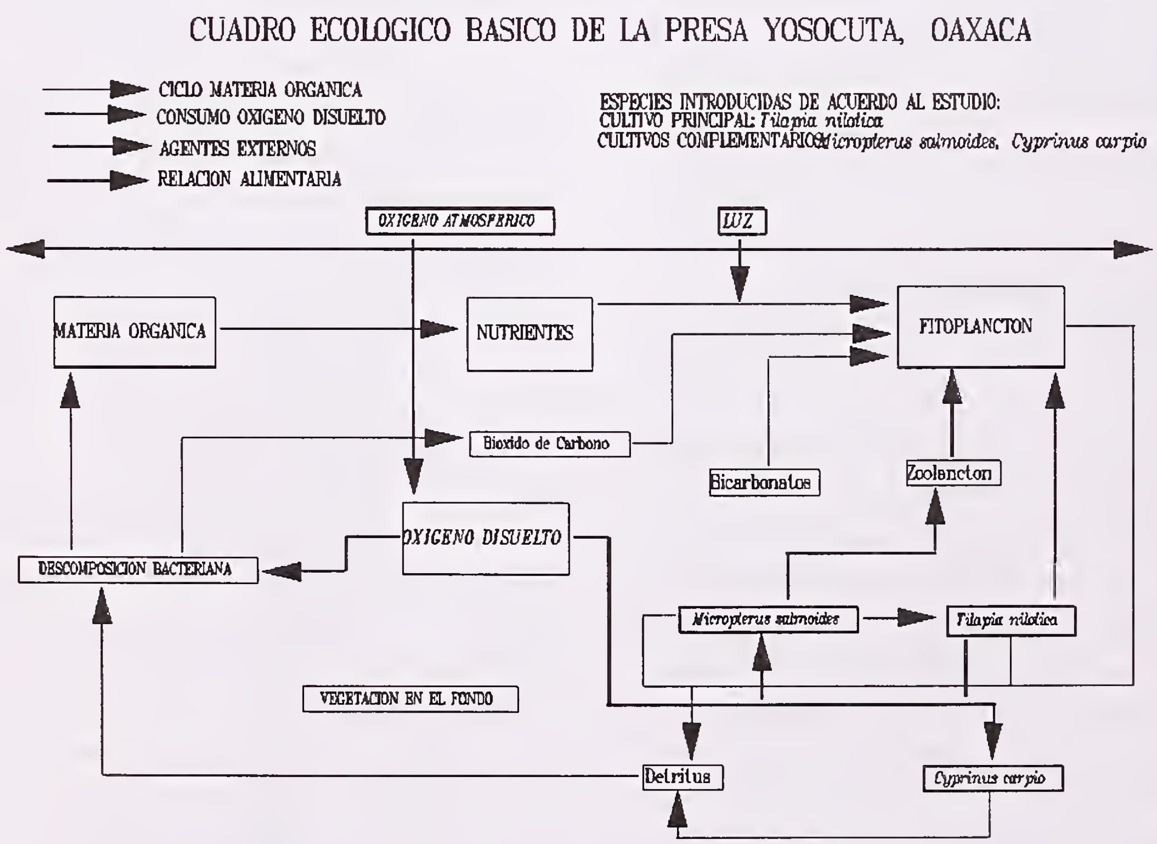


Figura 2. Interelaciones bióticas-abióticas y especies de peces introducidas

de los peces y los registros de las variaciones estacionales de los nutrientes inorgánicos.

Con el cumplimiento de los 3 ciclos anuales se logró que con estudios limnológicos básicos se dieran las bases en las que por un lado se conociera el marco ambiental del embalse y por otro lado, se introdujeran las especies de peces mas adecuadas a ese marco ambiental; así mismo con el seguimiento del desarrollo de las comunidades de peces introducidas, se estableció la actividad pesquera, beneficiando directamente a los habitantes ribereños del cauce original del Río Balsas.

Como complemento al trabajo anterior, se impartieron cursos de teoría y práctica sobre capacitación pesquera, con el fin de proporcionar conocimientos necesarios para la adecuada explotación y procesamiento del producto, incluyendo aspectos básicos de cooperativismo. También se hizo difusión extensa entre los pescadores sobre el conocimiento de aspectos limnológicos y biológicos más importantes que influyen en las poblaciones de peces que capturan, para responsabilizarlos sobre la explotación racional y sostenida del producto.

Durante los años 1990-1992 en períodos mensuales se efectuaron nuevos muestreos fisicoquímicos y biológicos en los sitios de muestreo originales del embalse, con el objetivo de comparar el marco ambiental en columna de agua, así como la evolución de la pesquería tanto comercial (*Tilapia*) como deportiva (*Micropterus*) establecidas en 1974. La variante en este ciclo fué que para 1992 se seleccionaron 4 estaciones de muestreo que fueran representativas de la presa (entrada del río, parte central, cooperativa y zona de cortina), para monitorearlos en forma trimestral, cubriendo las principales temporadas climáticas de la zona, así como los procesos de circulación y estratificación de la columna de agua, que habían sido detectadas tanto en el período 1971-1975 como durante 1990-1991.

El monitoreo en las estaciones representativas de las condiciones hidrológicas del embalse así como de los períodos críticos de lluvias, secas, estratificación y circulación, proporcionó información adecuada sobre el marco ambiental del sistema, reduciendo considerablemente el trabajo tanto de campo como laboratorio, así como hacer más eficiente el presupuesto para la investigación.

La experiencia de monitorear estaciones hidrológicamente representativas adquirida en la presa Yosocuta, se aplicó en la presa hidroeléctrica "EL Caracol", Guerrero, reservorio 6 veces mayor en área y con problemas similares como frecuentes mortandades de peces, tallas pequeñas y sin valor económico. Considerando las mismas temporadas climáticas críticas con efecto en el reservorio, se efectuaron monitoreos trimestrales de los principales parámetros fisicoquímicos en columna de agua durante el período 1992-1994 abarcando las diferentes zonas de cualquier reservorio propuesto por Thornton (1981), zona riparia, zona de transición y zona lacustre. Luego de considerar un total de 9 estaciones de muestreo, luego del análisis de datos obtenidos durante 1992 y 1993, se seleccionaron las estaciones representativas del embalse, 4 (influencia riparia), 6 (zona abierta o de transición), 7 (zona lacustre) y 9 (zona de cortina) (Figura 3).

Considerando la información de esas estaciones en 1994 y principios de 1995, se pudo establecer la dinámica de la circulación y estratificación de la columna de agua (Figura 4), así como los niveles en columna de agua con concentraciones de oxígeno disuelto, adecuadas para los organismos (Carranza y López, 1995). Se pudo detrminar también que el sistema se comporta como un lago meromíctico, esto es, que no presenta mezcla de su agua hasta el fondo; en invierno su circulación es parcial en la capa superficial lo cual ocasiona que la zona oxigenada apta para peces llega a la profundidad de 20 a 25 metros, reduciendo drásticamente el oxígeno luego de esta profunidad, hasta llegar a condiciones de anoxia en el fondo.

Partiendo de un período de trabajo intenso de 2 o 3 años en un número inicial de estaciones de muestreo que considere las diferentes condiciones hidrológicas del sistema como afluentes, asentamientos humanos, zona abierta, zona protegida del viento, etc., enmarcados en las zonas riparia, de transición y lacustre propuestos por Thornton, se puede seleccionar posteriormente las representativas de la dinámica ambiental del sistema, las cuáles serán monitoreadas durante los períodos de tiempo en que se manifiestan claramente las condiciones de la sequía o lluvia, o bien los patrones de circulación y estratificación. Por otro lado, de todos los parámetros fisicoquímicos se puede hacer también una adecuada selección de forma tal

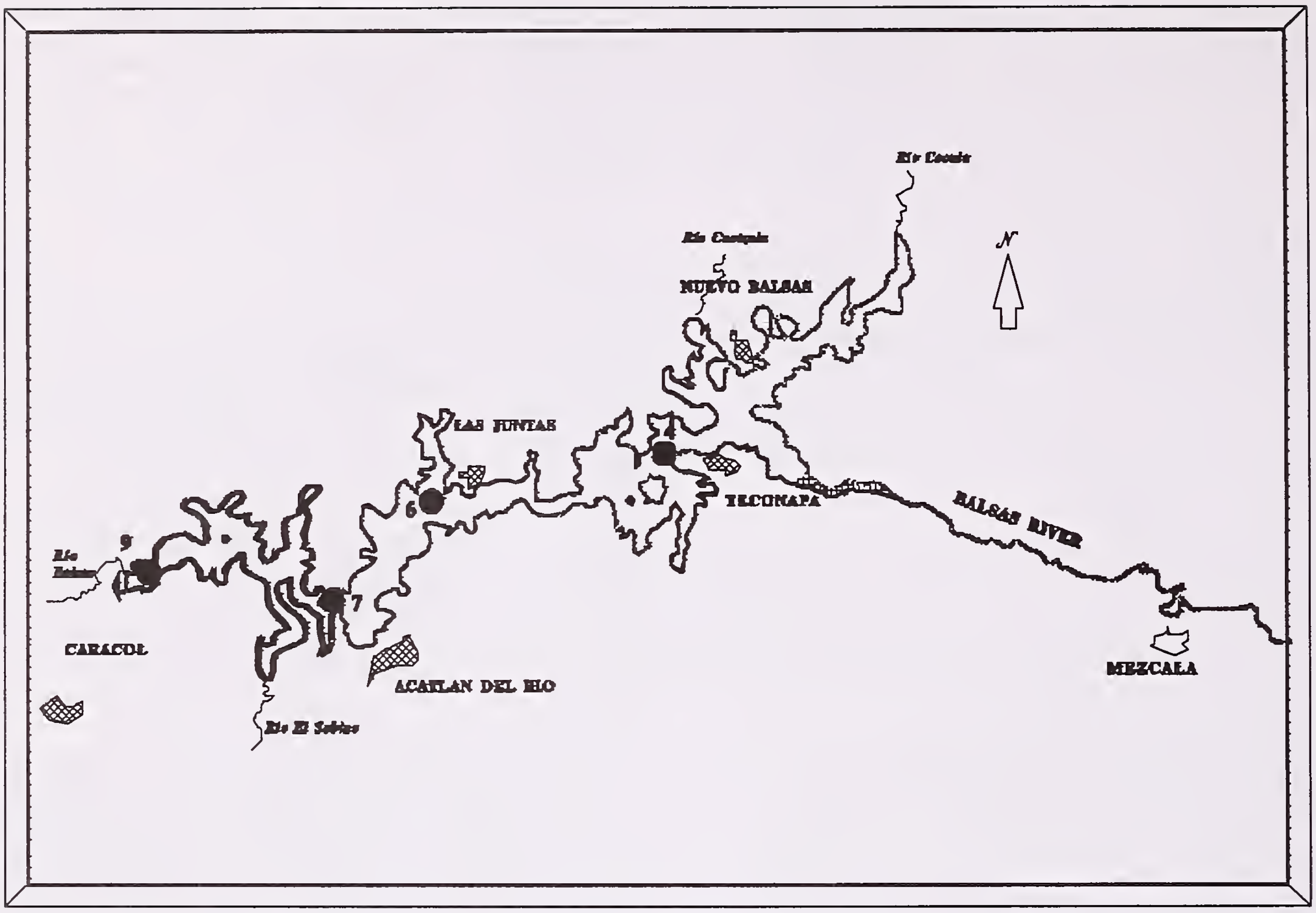
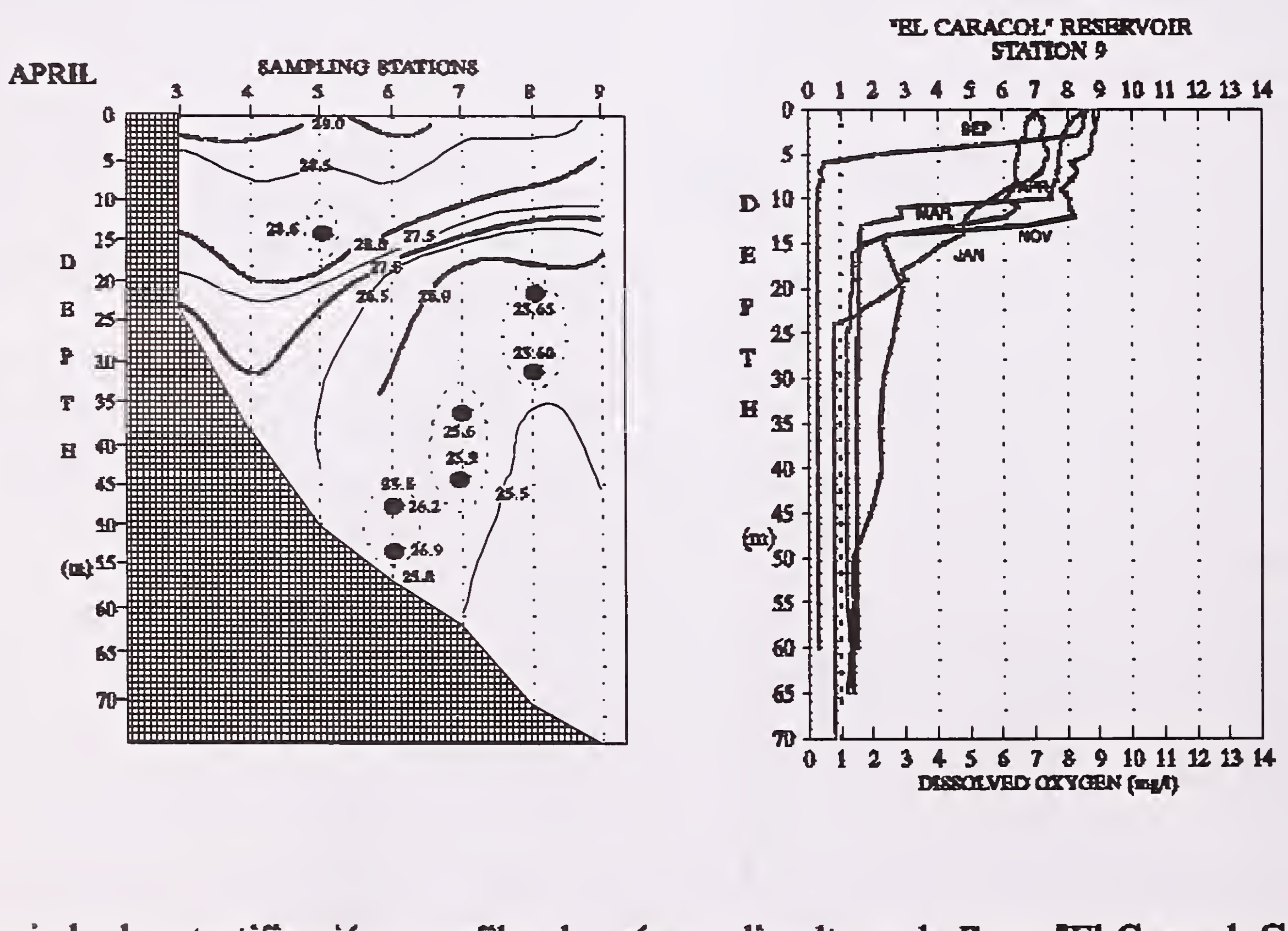


Figura 3. Mapa de la Presa Hidroeléctrica "El Caracol", Guerrero y las estaciones de monitoreo, durante 1994.



Periodo de estratificación y perfiles de oxígeno disuelto en la Presa "El Caracol, Gro.

Figura 4. Isotermas en columna de agua en el periodo de estratificación y dinámica de oxígeno disuelto en diferentes meses.

que como en nuestros ejemplos, con la dinámica de temperatura del agua, oxígeno disuelto, pH, potencial redox, conductividad eléctrica, alcalinidad total y nutrientes inorgánicos, puede obtenerse el marco ambiental general del reservorio.

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Estudios Basicos Para la Integración de un Programa de Manejo y Conservación de La Cuenca de La Babicora, México

Alberto Lafon[1]

Presentacion. La siguiente ponencia da un panorama de la region de la Babicora Chihuahua, como un lugar de importancia internacional para la conservacion de la biodiversidad. Se hace incapie en los pasos que fueron requeridos para la implementacion de este proyecto, sus antecedentes, tramites, avances y problematica detectada en el desarrollo del estudio como un ejemplo para aquellas instituciones que deseen proponer algun proyecto similar.

INTRODUCCION

Las lagunas de la Babicora, se encuentran ubicadas al noroeste del estado de Chihuahua, justo en las estibaciones de la sierra Madre Occidental. Si trataramos de definir la forma de las lagunas pudieramos decir que es una cuenca cerrada a manera de una celula con una serie de pequeñas lagunas en el nucleo, pastizales en las areas circundantes de las lagunas, areas de cultivo en el siguiente circulo y finalmente un anillo de areas forestales en la membrana de esta celula. En total de la cuenca abarca cerca de 200 mil hectareas de las cuales entre 10 y 11 mil son suceptibles de inundacion y cuya superficie varia de acuerdo a las precipitaciones anuales.

Para dar una idea de lo que esta area fue a fines del siglo pasado, mencionaremos que en 1887, la familia Hearst's adquirio esta area comprandola a diferentes propietarios e integrando una hacienda de aproximadamente 350 000 has. esta fue dividida en 9 propiedades entre los miembros de la familia dedicandola principalmente a la ganaderia.

Imaginar este lugar con una riqueza de paisaje y biologica similar al parque Yellowstone es algo que se viene a la mente cuando platica uno con los "viejos" de la Colonia, los cuales comentan: "habia manadas de berrendos en los planos y las ovejas eran atacadas por lobos y osos. Habia muchas truchas, castores y nutrias, y los restos de la cultura apache (Moctezumas) se podian encontrar por donde quiera".

A fines de 1936 el presidente Cardenas opto por dar las tierras a los campesinos expropiandolas a la familia Hearst's. En 1954 la Alta Babicora fue dividida en 12 colonias para 2,250 campesinos, donde cada uno recibio 25 has. para siembra y 50 de agostadero en mancomun para produccion de ganado, con una clausula que la restringia de venta para otros propositos. A partir de estas fechas los cambios se vinieron haciendo notorios y el aprovechamiento forestal y de los pastizales empezo a hacer estragos en los recursos naturales de la zona.

ANTECEDENTES

Dada su localizacion, las lagunas se constituyen en el principal sitio de invernacion de aves acuaticas migratorias de la ruta central para el norte de nuestro pais, se considera que el area hospeda cerca de 500,000 aves en epoca invernal y que si tomamos en

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consideracion a aquellas que usan esta zona como sitio de descanso durante la migracion este numero seria aproximadamente diez veces mayor. Las lagunas estan consideradas en el listado de humedales de importancia para Mexico, por la SEMARNAP y el Acta de Conservacion de Humedales de Norteamerica. Por estas caracteristica las lagunas han sido fuente de diversos estudios, principalmente hidrologicos, edafologicos y biologicos, dentro de estos ultimos y dado que se comparten distintas especies de aves migratorias con paises como EUA, URRSS y Canada, los estudios realizados han tenido un enfoque hacia estas especies, principalmente aves cinegeticas (Patos, Gansos y Grullas), asi como de especies "neotropicales" y de aves playeras.

Dentro de los estudios que han sido realizados en la zona, se cuentan con proyectos de turismo, de aprovechamiento cinegetico y de posibilidades de creacion de un santuario natural y proyectos de indole agropecuario como el drenado de las lagunas para incrementar la superficie agricola, motivo del origen de esta iniciativa.

El caso de Babicora, presenta una situacion similar a otras muchas areas del pais en donde la biodiversidad esta amenazada por la necesidad de produccion de alimentos, o bien por el uso mismo de la flora y fauna para la complementacion alimenticia y/o de ingreso economico para subsistencia. En esta area fueron diferentes organizaciones y dependencias las que realizaron estudios y proyectos que motivaron mayor atencion a la zona. Algunas de las entidades que empezaron a unir esfuerzos por proponer una iniciativa para la conservacion de este humedal fueron; La Universidad Autonoma de Chihuahua, La Universidad Estatal de Iowa, la Universidad Estatal de Nuevo Mexico y la Asociacion Proteccion de la Fauna Mexicana, todas en comun acuerdo con las dependencias encargadas de los recursos naturales de Mexico, EUA y Canada. Esta iniciativa tomo fuerza a traves de la propuesta ISU - UACH - FWS - SEDUE en 1992, habiendo sido turnada a las dependencias oficiales quienes sugirieron cambios y adecuaciones que posterior a realizadas se presentaron a los patrocinadores, quienes en su primera etapa fueron la Fundacion Turner y Ducks Unlimited, pasando posteriormente al Consejo de Conservacion de Humedales de Norteamerica para su aprobacion.

LA ORGANIZACION DEL ESTUDIO

Aprobada la propuesta se realizaron reuniones de planeacion entre los futuros participantes, integrando 4 equipos de trabajo: Recursos Naturales, que se encargaria de todos aquellos factores naturales presentes en el area incluyendo, flora, fauna, clima, suelo e hidrologia. Estudios socioeconomicos, que trabajo con los aspectos referentes a ese tema, Sistemas de Produccion que se encargo de la caracterizacion de los sistemas de produccion agricola, pecuario y forestal y un cuarto grupo que se encargo de el diagnostico para la educacion ambiental y el diseño de material aplicable para la zona.

Posterior a la integracion de los equipos, se iniciaron las actividades habiendo participado un total de 27 tecnicos, se incluyeron dentro de este equipo a historiadores y personal de desarrollo turistico, quienes realizaron un papel primordial en el analisis de alternativas de ingreso regional. Durante este estudio fue clave la participacion y buena disposicion de los pobladores del area, lo cual hizo posible concluir esta etapa y poder pensar en dar inicio a la siguiente.

RESULTADOS DE LA PRIMER ETAPA

Como resultados de la primer etapa, se creo la base de datos del area, georefiriendo la informacion para su manejo en sistemas (SIG) que facilitaran el manejo de la misma. En los aspectos de vegetacion se tuvieron 7 nuevos hallazgos para la zona (2 nuevas especies para la ciencia y 5 no reportadas en el area). Se observo que el principal problema de la zona es el sobrepastoreo por sobrecarga de los agostaderos. La zona forestal esta siendo poco utilizada comercialmente sin embargo fue fuertemente aprovechada en decadas pasadas, al respecto cabe hacer notar que el tradicionalismo en el uso "domestico" de arbolado para leña y postes tiene un efecto de "area de castigo" en forma radial en los poblados, que es directamente proporcional al tamaño de la comunidad. La vegetacion como habitat para especies sivestres no tiene fuertes impactos sin embargo se requiere de concientizacion para disminuir el uso de arbolado sobremaduro. Se detecto que el area es un punto importante durante la migracion de aguila calva ademas de otras especies

y que la observacion de aves y la organizacion cinegetica puede ser una alternativa para la zona en terminos economicos. Desde el punto de vista hidrologico se observo que la cuenca tiene grandes depositos de sales que pueden convertirse en un serio problema si se llevan a cabo los planes de desecacion de las lagunas. El uso de las areas agricolas es para Maiz, Frijol y avena principalmente cultivandose tambien papa y frutales. El esquema de produccion ganadero es en base a la produccion de becerro para exportacion, sin embargo las tasas de produccion son muy bajas (34% de paricion) teniendo serios problemas con ganado improductivo tanto vacuno como caballar. El analisis socioeconomico detecto demandas de asistencia tecnica real y oportuna, apoyos para organizacion campesina, creditos y educacion ambiental. Los campesinos del area solicitaron tambien apoyo para motivacion a la produccion y seriedad en el seguimiento de programas en la zona.

PROBLEMATICA DURANTE EL DESARROLLO DEL TRABAJO

Los principales problemas encontrados para la realizacion de este programa fueron: 1. Los tramites para someter la propuesta de apoyo. En este caso mucho depende de las partes involucradas y los "socios" que propongan el proyecto. Se puede considerar que el apoyo depende de el interes personal del grupo de investigadores y empleados oficiales que se interesen por la propuesta. 2. La consecucion de patrocinadores no gubernamentales, en este punto se requiere de interes de los socios nuevamente y de la oportunidad para mostrar los beneficios futuros del proyecto a los posibles patrocinadores. 3. La integracion del equipo de trabajo, es necesario para poder llevar a cabo un proyecto de esta indole que se trabaje en forma interdiciplinaria e interinstitucional, cuidando la armonia en las relaciones entre participantes. 4. Convencimiento de los pobladores de las comunidades. Resulta dificil dar inicio a un programa de este tipo cuando se tienen proyectos gubernamentales previos para "desarrollo" de area con un programa completamente opuesto al de "conservacion" sugerido. de igual manera se encontraron dificultades durante el desarrollo de las actividades por celo entre grupos opuestos o bien entre poblados. Otro punto que representa problema es la falta de credibilidad de los campesinos hacia programas de nueva creacion en donde el "seguimiento" es reclamado para esfuerzos similares realizados con anterioridad. 5. Logro del enfoque de cada participante del grupo de trabajo. La diferencia de especializacion de tecnicos participantes pueden ocacionar dificultades en el desarrollo de estos estudios, en donde la definicion exacta de perticipacion es necesaria para evitar gasto de tiempo y recursos.

6. Transferencia de tecnologia y alternativas. El contar con un excelente cuerpo tecnico para el diagnostico de un area no garantiza que los resultados obtenidos vayan a ser aplicados. Se puede decir que el trabajar con las comunidades en el mundo real es algo que pocos tecnicos realizan, teniendo a la fecha una deficiencia extrema de personal preparado en extencionismo. De igual forma la misma apatia de los campesinos requiere ser superada a traves de trabajo conjunto entre tecnicos y pobladores de las areas.

CONCLUCIONES Y RECOMENDACIONES

A manera de conclucion, podemos sugerir que se piense en la elaboracion de programas similares para la conservacion de humedales en por lo menos aquellas areas detectadas como de importancia e traves del listado de humedales prioritarios para Mexico, para ello es recomendable establecer un grupo tecnico que ayude a marcar las politicas de conservacion y manejo de estas areas. La buena relacion Mexico-EUA, da oportunidad de obtener apoyo de instituciones patrocinadoras para la realizacion de estudios de conservacion de humedales, iniciativa que debera ser promovida y apoyada por los organismos gubernamentales respectivos. Se requiere de igual manera la promocion de trabajos y foros de participacion comunitaria que ayuden a la relacion pueblo-gobierno y al entendimiento de las actitudes de las comunidades hacia los recursos naturales, esto permitira craer las lineas de accion para lograr el manejo y la conservacion de nuestros recursos naturales. Se necesita en forma urgente, que las instituciones educativas y de servicio al campo den una mejor preparacion a sus egresados y trabajadores para lograr el entendimiento entre los pobladores de comunidades y los tecnicos, esto con el fin de implementar opciones productivas y eficientizar la transferencia de tecnologia.

Ecosistemas Costeros en México

Francisco Contreras Espinosa[1]

En primer lugar es necesario establecer cuáles son los ecosistemas acuáticos costeros más relevantes, sobre todo porque el país está rodeado por una línea litoral de 11,592.77 km. A lo largo de ambos litorales 1' 567,300 hectáreas están cubiertas por superficies estuarinas; el Pacífico posee 892,800 y el Golfo de México y el Caribe 674,500 (INEGI, 1984), por lo que se aprecia, los ecosistemas costeros de características estuarinas ocupan un importante papel en la conformación litoral (Tabla 1).

Estos ecosistemas acuáticos costeros se dividen en tres grandes grupos:

a) los dominados por los escurrimientos dulceacuícolas, como los pantanos, ciénegas y ciertos tipos de marismas y esteros. Estos ecosistemas se localizan principalmente en zonas asociadas a caudales importantes como los ubicados en la parte sur de México (Tabasco, Sur de Veracruz). Las áreas más conocidas son los pantanos de Centla Tab., El Huayate y el Maragato y Cantileña Chis. y las zonas asociadas a la laguna de Alvarado con los ríos Papaloapan y Acula, Ver.

b) los estuarinos, cuyo ejemplo son las lagunas. Sobresalen por sus dimensiones las lagunas de: Escuinapa y Yávaros Son.; Huizache-Caimanero costeras y que son el resultado de la mezcla de los dos tipos de agua: la proveniente de los ríos y el mar Sin.; Agua Brava-Teacapán Nay.; Superior e Inferior Oax.; Mar Muerto Oax./Chis.; Madre Tamps.; Tamiahua, Mandinga, Alvarado y Sontecomapan Ver.; Carmen-Machona y Mecoacán Tab; Términos Camp. y Celestún Yuc.

c) los dominados principalmente por la influencia marina, por ejemplo: las bahías, ensenadas y roquetas y cuya mayor incidencia se da en áreas con escasos o nulos escurrimientos de agua dulce y/o climas áridos, como en las penínsulas de Baja California y Yucatán, Sonora y parte de Oaxaca. Destacan por su extensión las bahías de: Todos Santos y San Quintín en Baja California; Vizcaino, San Ignacio, Magdalena-Almejas, La Paz y Concepción en Baja California Sur; Adair, Guaymas y Lobos Son; Mazatlán Sin.; Manzanillo Col.; Huatulco Oax.; Acapulco Gro.; Sian Ka'an, Espíritu Santo y Chetumal en Quintana Roo.

De los ecosistemas costeros, las lagunas sobresalen por su número (cerca de 130), importancia económica (son áreas de pesca intensiva aunque artesanal y medio de vida de miles de pescadores), ubicación (están distribuidas a lo largo de ambos litorales), importancia biológica (son hábitat de muchas especies y sitios de alevinaje, reproducción y resguardo), productividad potencial (son ecosistemas que, comunmente, poseen una elevada productividad primaria) y extensión (desde cientos hasta miles de hectáreas). Por lo anteriormente expuesto, resulta paradójico que en el país no exista una política dirigida a la conservación, manejo y aprovechamiento racional sobre estos ecosistemas.

Tabla 1. Extensión litoral y superficies estuáricas de México (INEGI, 1984).

	Línea litoral (km)	Superficie estuárica (Ha)
Pacifico		
B. C.	1,555.23	74,800
B. C. S.	2,705.39	224,000
Sonora	1,207.81	51,700
Sinaloa	640.17	221,600
Nayarit	300.41	92,400
Jalisco	341.93	3,200
Colima	139.22	8,200
Michoacán	246.76	500
Guerrero	484.94	22,700
Oaxaca	597.51	106,900
Chiapas	255.69	87,000
Golfo de México		
Tamaulipas	457.72	231,200
Veracruz	745.14	116,600
Tabasco	183.86	29,800
Campeche	523.30	196,000
Yucatán	342.47	13,600
Q. Roo	865.22	87,300

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UNA APROXIMACIÓN METODOLÓGICA

El estudio sistemático de los ecosistemas costeros ha sido realizado principalmente por instituciones de educación superior, tanto Universidades como Centros de investigación diseminados por toda la república mexicana; gracias a esta contínua labor y en los momentos actuales, se cuenta con una considerable cantidad de información sobre las características de estos ambientes y que pudieran propiciar una primera e importante, aunque general, evaluación ecológica. En este sentido, la evaluación ecológica de un ecosistema acuático debe basarse en el conocimiento de los parámetros fundamentales que caracterizan a dichos ecosistemas, por lo tanto, primeramente hay que establecer cuáles y cuántos son los factores que podrían catalogarse como tales.

Los ecosistemas costeros son cuerpos acuáticos complejos pero que, en primera instancia y en la mayoría de ellos, se manifiestan como un efecto hidrológico resultado del encuentro entre dos tipos de agua y en donde la cuantificación y seguimiento de algunos factores fisico-químicos resulta imprescindible en el conocimiento y manejo integral de estos ambientes.

De lo anterior se desprende que cuando se pretende conocer y entender a estos ecosistemas por primera vez, generalmente se hace tomando como referencias básicas sus características abióticas, es decir, las físicas (como vientos y mareas), y las químicas (como salinidad, oxígeno disuelto, pH y temperatura). Adicionalmente, se determina la cantidad de nutrientes (amonio, nitratos, nitritos y fosfatos) y como resultado de la interacción espacio-temporal de los anteriores factores, se cuantifica la productividad primaria (biomasa fitoplanctónica y/o macrofitas acuáticas) que significa la respuesta ecológica del sistema, en términos de flujo energético, éste se ve incrementado por el aporte de biomasa de los manglares incorporándose a la cadena detritívora (Conant *et al.*, 1983, Brower y Zar, 1974, Strickland y Parsons, 1968).

Paralelo a lo anterior, el estudio básico se acompaña del conocimiento de los principales componentes de la biota lagunar vegetación circundante y sumergida, fitoplancton, zooplancton, bentos e ictiofauna, lo que adquiere especial significado, ya que estas comunidades se desarrollan primordialmente condicionadas a las características ambientales particulares del ecosistema en estudio. Bajo esta óptica, debe contemplarse la identificación de los principales elementos derivados de las actividades antropogénicas que se desarrollan, tanto en las proximidades del cuerpo acuático, como en las tierras altas. Lo anterior es de suma importancia porque ningún proyecto de aprovechamiento tendrá éxito si el ecosistema se encuentra amenazado con las descargas de aguas residuales de industrias o asentamientos humanos que no estén eficientemente tratadas (FAO, 1995).

En relación con lo anterior, la búsqueda y localización de la información pertinente a la ecología de los ecosistemas costeros es imprescindible en la integración y conformación de cualquier proyecto. Cabe aclarar que dicha información es heterogénea y disímbola, ya que existen áreas del conocimiento en donde hay una considerable cantidad, en cambio en otras, no hay la mínima indispensable.

El panorama anterior es un acercamiento de lo que es deseable conocer para llevar a cabo un seguimiento adecuado de nuestros ecosistemas litorales; por otro lado es necesario una conceptualización como la siguiente (Tabla 2):

Finalmente, es necesario dejar establecido que en la medida de que no existan estudios básicos realizados en un número significativo de ecosistemas litorales, es muy cuestionable el establecimiento de parámetros que pudiesen ser utilizados como patrón para conocer límites que significaran anomalías con respecto a la calidad del agua.

En el caso de aguas dulces, diversas organizaciones tanto nacionales como internacionales, han podido fijar valores de algunos parámetros fisico-químicos que han sido establecidos como normas para el uso del agua con diferentes fines (recreación, riego, acuicultura, potable, etc.); sin embargo y en el caso de aguas estuarinas y/o lagunares, lo anterior no es aplicable debido a la elevada variación de algunos elementos abióticos normales en estos ecosistemas, sobre todo en los tropicales. Por lo anterior y para estas regiones, es imprescindible establecer cuales son los intervalos "normales" para un número determinado de variables significativas que pudiesen ofrecer claves y que indicaran eventuales anomalías.

MONITOREO DE ECOSISTEMAS COSTEROS

El paso inicial y fundamental para conocer y comprender la dinámica de los ecosistemas costeros está en la cantidad y calidad de la información que se ha generado durante años de trabajo. Bajo esta

Tabla 2. Principios ecologicios, manejo y acciones inaceptables.

Princípios ecológicos	Princípios de manejo	Acciones inaceptables
Integridad del ecosistema	Conceptualizar al sistema como una unidad	Conceptualización parcializada
Interrelaciones con otros hábitats	Conocer y proteger	Parcelar alternativas de uso o mitigaciones; secar pantanos o alterar hábitats circundantes intermareales
Insumos de agua dulce y marina	Respetar el flujo natural y su calidad	Modificar o alterar; introducir desechos tóxicos; modificar bocas de comunicación con el mar sin estudios previos
Circulación de la cuenca	Respetar el ciclo anual	Modificar o alterar por drenaje o relleno
Flujos de energía	Proteger y optimizar	Alterar o modificar
Capacidad de almacenamiento	Proteger totalmente	Alterar o modificar
Presencia de nutrientes	Evaluar y conocer las concentraciones normales y su variación local	Incrementar su presencia (principalmente el nitrógeno)
Cantidad de luz	Preservar el régimen natural	Incrementar la turbidez
Vegetación circundante y sumergida	Preservar el borde vegetativo y las áreas de pastos	Talar o eliminar el borde vegetativo
Temperatura, salinidad y oxígeno disuelto	Evaluar, conocer y respetar los valores normales y su variación estacional	Alterar o modificar; en el caso de las lagunas tropicales propiciar el aumento de la temperatura

perspectiva, la Universidad Autónoma Metropolitana-Iztapalapa y desde hace 17 años, ha apoyado la línea de investigación en lagunas costeras mexicanas en dos vertientes:

a) la investigación sobre el comportamiento hidrológico y productivo; estudios que hasta la fecha han permitido el conocimiento, cuantificación y discusión de los principales parámetros que caracterizan a estos cuerpos lagunares en 39 áreas de estudio y,
b) la localización y captura de la información científica alrededor de estos ecosistemas. Lo anterior ha dado origen al Centro de Documentación sobre Ecosistemas Litorales Mexicanos (CDELM), base de datos bibliográfica en donde es posible acceder a toda la información científica que ha sido reunida y que significa 4,000 referencias bibliográficas con resumen incluido para la mayoría de los ecosistemas (Castañeda y Contreras, 1993, 1994a, 1994b, 1994c y 1995).

Sobre el primer aspecto y como un aporte de la Universidad Autónoma Metropolitana a esta reunión, se exponen a continuación algunos resultados de investigaciones realizadas en 39 lagunas costeras mexicanas, con el fín de establecer algunos intervalos de valores de algunas característica propias de estos ecosistemas.

Las dos propiedades más sobresalientes de las lagunas costeras son la salinidad y el oxígeno disuelto. La primera les confiere su particular biota asociada y hábitats, y el segundo es un indicativo confiable de los procesos provenientes primordialmente de los productores primarios (Tabla 3, 4).

Clasificación de lagunas costeras según sus valores de Salinidad.

1.1 Lagunas con fuertes influencias de aportes terrígenos. Salinidad por debajo de las 5 °/oo de promedio anual. Lo anterior implica, algunas veces, intervalos amplios pero cuyos valores promedio mantienen condiciones de oligohalinidad.

1.1. Lagunas oligohalinas.

Ejemplos: Golfo de México, Tlalixcoyan y río Calzadas en Veracruz. En el Pacífico: Mitla, Gro. Manialtepec, Oax. Buenavista, Chis.

1.2 Lagunas con característcas estuarinas, debidas al intercambio de agua y una buena mezcla, con dos subcategorías:

1.2.1. Salinidad cuyo promedio anual va de 5 a 18 °/oo

1.2.1. Lagunas mesohalinas.

Tablas 3 y 4. Agrupamiento de lagunas según sus valores promedio de salinidad (°/oo) y oxígeno disuelto (ml/l).

Salinidad °/oo				
Golfo de México				
0.0 - 10.0	10.0 - 20.0	20.0 - 30.0	30.0 - 40.0	> 40.0
Tlalixcoyan	Pueblo Viejo	Tamiahua	Tampa. 80	Madre
Calzadas	Mancha	Tampa. 90	Términos	
Mecoacán	Camaronera	Tuxpan		
	Alvarado	Mandinga		
	Sontecomapan	Carmen		
	Ostión	Machona		
		Celestún		
Pacífico Sur				
Mitla	San Marcos	Nuxco	Chacahua	Corralero
Manialtepec	Chautengo	Joya-Buenav.	Pastoría	Mar Muerto
Carretas	Pereyra			Sup. e Inf.
Chantuto	Bobo			
Panzacola	Cerritos			
	Buenavista			
	Teculapa			
	Campón			

Oxígeno Disuelto ml/l				
Golfo de México				
2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	5.0 - 6.0	6.0 - 7.0
	Mancha	Pueblo Viejo	Madre	Tamiahua
	Mandinga	Tampa. 80	Tampa. 90	
	Tlalixcoyan	Tuxpan	Camaronera	
	Calzadas	Alvarado	Sontecomapan	
	Mecoacán	Ostión		
		Carmen		
		Machona		
		Términos		
Pacífico				
Manialtepec	Nuxco	Mitla		
Bobo	San Marcos	Chautengo		
Cerritos	Joya-Buenav.	Corralero		
Buenavista	Pereyra	Chacahua		
Panzacola		Pastoría		
Teculapa		Sup. e Inf.		
Campón		Mar Muerto		
		Carretas		
		Chantuto		

Ejemplos: Camaronera, Alvarado, Sontecomapan y Mecoacán en el Golfo de México. Por parte del Pacífico: Chautengo,Gro., Manialtepec, Oax., Carretas,
Pereyra, Bobo, Cerritos, Chantuto, Teculapa, Panzacola y Campón en Chiapas.
1.2.2. de 18 a 30 °/oo
1.2.2. Lagunas polihalinas
Ejemplos: Pueblo Viejo, Tamiahua, Tampamachoco 1990, Tuxpan, Mancha, Mandinga y Ostión en Veracruz; Carmen y Machona, Tab. y Celestún, Yuc. Pacífico: Nuxco y San Marcos, Gro.; Joya-Buenavista, Chis.
1.3 Lagunas con marcada influencia oceánica. Salinidad que va de las 30 a las 40 °/oo.
1.3. Lagunas eurihalinas
Ejemplos: Términos, Camp. Chacahua-Pastoría, Oax.
1.4 Lagunas que por una elevada evaporación, poca circulación, recambio o inclusive alteraciones humanas en su cuenca hidrológica, manifiestan salinidades por arriba de las 40 °/oo.
1.4. Lagunas hiperhalinas
Ejemplos: Madre, Tamps.; Corralero, Superior e Inferior y Mar Muerto, Oax.
Clasificación de lagunas costeras según su contenido de Oxígeno disuelto.
1.1 Valores promedio entre los 2 y 3 ml/l, concentraciones consideradas nocivas para la biota acuática.
Lagunas hipóxicas
Ejemplos: Manialtepec, Oax.; Bobo, Cerritos, Buenavista y Teculapa en Chiapas.
1.2 Valores promedio entre 3 y 5 ml/l, óptimos para el desarrollo de organismos.
Lagunas óxicas
Ejemplos: La mayoría de las lagunas costeras, tanto en el Golfo como en el Pacífico.
1.3 Valores que rebasan los 5 ml/l. Característico de aguas muy productivas debido a que estas concentraciones representan, en la mayoría de los casos, niveles de sobresaturación del gas cuyo origen se presume en los productores primarios autóctonos.
Lagunas hiperóxicas.
Ejemplos: Madre, Tamps.; Tampamachoco, Tamiahua y Camaronera en Veracruz.

NUTRIENTES

Sin embargo, uno de los elementos más importantes para evaluar el estado ecológico de los sistemas costeros estuarinos es la medición de su cantidad de nutrientes, ya que son éstos los responsables, en primera instancia, de la productividad primaria pero también son los causantes de la

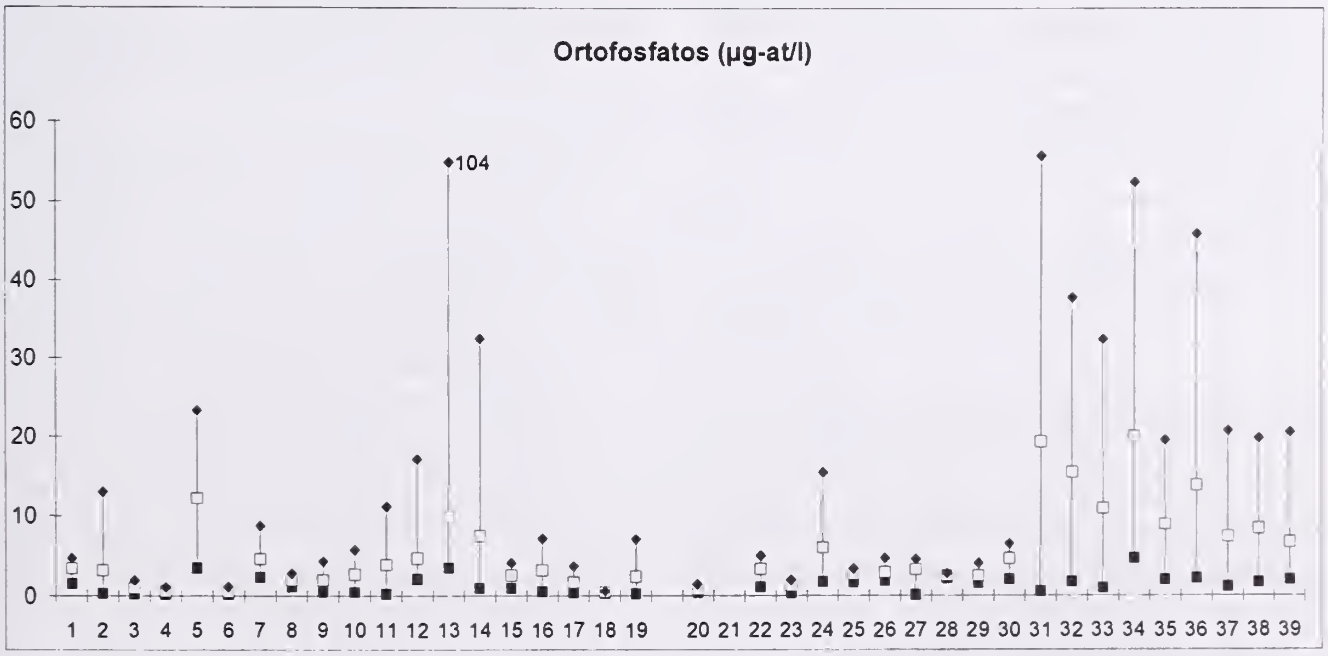

Figura 1. Concentración de ortofosfatos en 39 lagunas.

eutroficación. La mayoría de los ecosistemas mexicanos presentan elevadas cantidades de nutrientes, por lo que son considerados como levemente eutróficos (Mee, 1978; Contreras,1993). En este sentido, el aumento en la presencia de formas nitrogenadas o fosfatadas se reflejarán alterando los patrones normales de la productividad primaria y/o en la presencia de clorofila *a*, tomada ésta como un índice de la biomasa fitoplanctónica.

Por los datos recabados hasta el día de hoy, todo parece indicar que la presencia de fósforo permanece entre el intervalo de <0.01 a $5.0 \mu g$-at/l (tabla 5 y figura 1) y es la principal causa del incremento de la presencia de clorofila a; concentraciones mayores usualmente están relacionadas con ecosistemas de características eutróficas. Sin embargo y a pesar de lo anterior, la productividad no alcanza valores extraordinarios debido a la no proporcionalidad del Nitrógeno, esto

Tabla 5. Agrupamiento de lagunas costeras con base en el promedio de concentración de fosfatos.

Ortofosfatos µg-at/l				
Golfo de México				
0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 -20.0	> 20.0
Madre	Ostión	Tampa. 90		Calzadas
Pueblo Viejo				
Tamiahua				
Tampa. 80				
Tuxpan				
Mancha				
Mandinga				
Camaronera				
Alvarado				
Tlalixcoyan				
Sontecomapan				
Carmen				
Machona				
Mecoacán				
Términos				
Celestún				
Pacífico				
Nuxco	Corralero	Chantuto	Carretas	
San Marcos	Buenavista	Bobo	Cerritos	
Chautengo	Teculapa		Pereyra	
Chacahua	Panzacola			
Pastoría	Campón			
Manialtepec				
Sup. e Inf.				
Mar Muerto				
Joya-Buenav.				
25 = 65 %	6 = 15 %	3 = 8 %	3 = 8 %	1 = 2 %

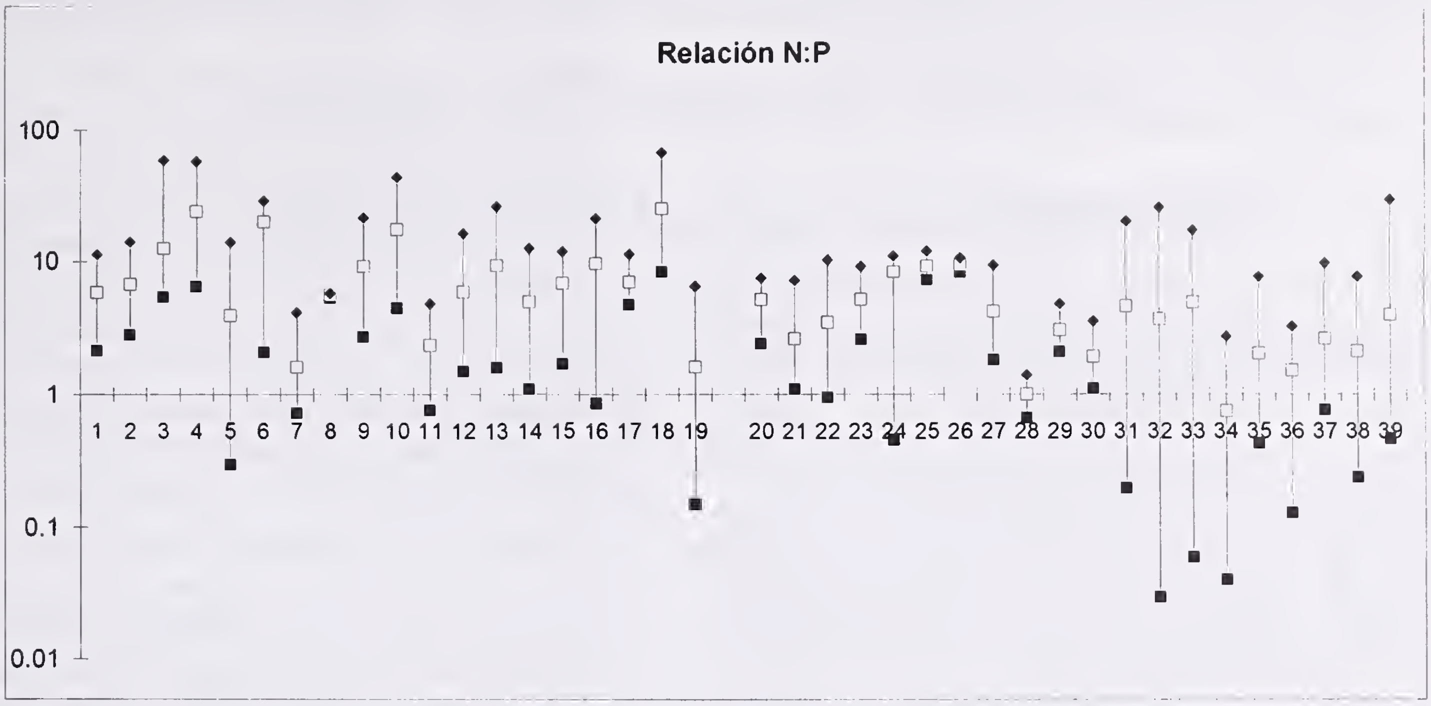

Figura 2. Relación N:P para 39 lagunas costeras mexicanas.

es, de una baja relación N:P (figura 2); de lo anterior se deduce que el insumo de nitrógeno en una laguna costera, vendría a ser la clave de la eutroficación del sistema, por lo que un seguimiento y control adecuado de sus fuentes debe ser implementado a la brevedad.

EL PROBLEMA DE LA CONTAMINACIÓN

Finalmente, habría que destacar algunas consideraciones alrededor del problema de la contaminación ya que, la creciente degradación de los ecosistemas costeros tiene dos vertientes interpretativas:

a) La contaminación por efluentes provenientes de actividades humanas (hidrocarburos, metales pesados, plaguicidas, bacterias coliformes y microorganismos asociados, etc.) y,
b) la alteración de hábitats asociados al sistema; ésta es más grave pues los cambios inducidos principalmente por la ganadería y agricultura en tierras aledañas o circundantes, generan modificaciones usualmente irreversibles, como lo son la desforestación y la alteración de los flujos hidráulicos.

En el primer caso, a pesar de que existe suficiente información (Vázquez-Botello y Ponce,1991), es urgente una colaboración entre los sectores involucrados para llevar a cabo una acción conjunta para establecer, en primer lugar, una intercalibración entre los métodos usuales para la evaluación de los contaminantes más frecuentes; y en segundo lugar, determinar los intervalos específicos para los sistemas costeros, tomando en cuenta el grado de intercambio de agua con el mar adyacente, que en algunos casos es pobre.

En el segundo caso, es imprescindible una planificación de las actividades económicas en la planicie costera y tierras altas vinculadas a ésta; regular el crecimiento de la ganadería, principalmente la localizada hacia las zonas tropicales y que conlleva a la tala de selvas y manglares. Por otro lado, la discusión previa con especialistas sobre los programas que realiza la Comisión Federal de Electricidad, sobre todo por la influencia que la construcción de presas pueda tener tierras abajo.

LAS PERSPECTIVAS A FUTURO

La información recopilada hasta la fecha en la Universidad junto con la reciente creación del Sistema de Información Geográfica, son la base de un proyecto para la planificación y ordenamiento de la zona costera mexicana y entre cuyos principales objetivos están los de:

a) generar una base de datos gráfica por medio de imagenes remotas del litoral mexicano

b) apoyar programas de evaluación, identificación de recursos, planificación territorial y recuperación de áreas lagunares y costeras.

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El Diagnóstico del Potencial Productivo de las Tierras Agricolas en México

José Ariel Ruiz Corral[1] en Carlos Sánchez Brito[2]

Ante la inminente implementación extensiva del Tratado de Libre Comercio de Norteamérica (NAFTA), en México existe la necesidad de inventariar los recursos del medio físico-biológico disponibles para el desarrollo de la agricultura, ganadería y explotación forestal.

En relación a esta tarea, el Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) se ha involucrado en los últimos años con el diagnóstico del potencial productivo de las tierras agrícolas.

Para alcanzar este objetivo el INIFAP ha tenido que desarrollar una estretegia de trabajo la cual ha requerido la implementación de una base de datos cartográficos del medio físico-biológico mediante el uso de sistemas de información geográfica (GIS). Esto ha llevado a la instalación de una red de módulos de GIS que actualmente consta de cinco estaciones; éstas están lozalizadas en:

a) Cd. Obregón, Sonora
b) Guadalajara, Jalisco
c) Calera, de V.R., Zacatecas
d) Toluca, México
e) Cotaxtla, Veracruz

La estrategia de trabajo tiene como salida:

La identificación de sistemas de producción agropecuarios y forestales potenciales desde el punto de vista agroecológico y que representen un bajo nivel de impacto ambiental para contribuir a la difusión de usos racionales del suelo.

DIAGNÓSTICO DE POTENCIAL PRODUCTIVO

La identificación de sistemas de producción potenciales se realiza mediante la comparación de los requerimientos agroecológicos de las especies vegetales en evaluación con las disponibilidades del medio físico de la región en estudio. Para ello, el INIFAP ha desarrollado, como ya se mencionó anteriormente, una base de datos cartográficos del medio físico-biológico, la cual se encuentra agrupada a nivel estatal y una base de datos de requerimientos clima-suelo-topografía de especies vegetales de uso agrícola, pecuario y forestal.

BASE DE DATOS DE REQUERIMIENTOS AGROECOLÓGICOS DE LOS CULTIVOS

Esta base de datos incluye alrededor de 60 especies cuyos requerimientos se caracterizan en función de las siguientes variables:

Clima:

Rango de temperaturas de adaptación
Rango de temperaturas óptimas
Sensibilidad al fotoperíodo
Uso consuntivo
Rango de precipitación para adaptación
Rango óptimo de precipitación
Radiación solar

Suelo:

Profundidad
Textura
pH
Conductividad eléctrica

Topografía:

Rango de altitud para adaptación

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Rango óptimo de altitud
Rango óptimo de pendiente
Exposición del terreno

Estos requerimientos agroecológicos han sido obtenidos y constantemente se actualizan a través de las siguientes fuentes:
a) Investigación documental
b) Experimentación en campo
c) Experimentación en ambiente controlado

Cabe mencionar que esta última fuente de información es apenas incipiente, ya que requiere de instrumentación costosa. Sin embargo, es una de las áreas de investigación que actualmente se consideran prioritarias dentro del esquema de investigación de INIFAP, debido a que no existe suficiente información a nivel mundial sobre las necesidades ambientales de las especies vegetales de origen tropical y subtropical con adaptación a México.

BASE DE DATOS CARTOGRÁFICOS DEL MEDIO FÍSICO

A nivel nacional

En forma extensiva para el territorio nacional, el INIFAP cuenta actualmente con una base de datos cartográficos procesada y documentada en los GIS IDRISI y Arc-INFO. Las variables de las que se disponen mapas temáticos son:
a) Temperatura máxima promedio por mes y anual
b) Temperatura mínima promedio por mes y anual
c) Temperatura media por mes y anual
d) Temperatura diurna por mes y anual
e) Temperatura nocturna por mes y anual
f) Precipitación promedio por mes y anual
g) Evaporación promedio por mes y anual
h) Cociente precipitación/evaporación por mes, anual y estacional.
i) Unidad de suelo (Sistema de clasificación de FAO)
j) Textura (A semidetalle)
k) Fases físicas
l) Fases químicas
m) Areas de litosoles
n) Cuerpos de agua
o) Areas ocupadas por centros poblacionales
p) Pendiente del suelo
q) Altitud

Estas imágenes cuentan con una área mínima cartografiable de 900 x 900 m (81 ha) en todos los estados de la República.

Las imágenes de variables climatológicas fueron generadas mediante programas de interpolación, utilizando información mensual de temperatura máxima, temperatura mínima, precipitación y evaporación correspondiente a 1500 estaciones meteorológicas emplazadas a lo largo del territorio nacional y que corresponden a la Red de Estaciones Meteorológicas del Servicio Meteorológico Nacional (SMN).

En los programas de interpolación se consideraron factores de corrección por altitud para las variables de temperatura y evaporación.

Las imágenes correspondientes a variables edáficas se obtuvieron mediante digitalización de cartas temáticas correspondientes a la colección cartográfica del Instituto Nacional de Estadística Geografía e Informática (INEGI).

Por último, las imágenes de aspectos topográficos se obtuvieron a través del GIS IDRISI haciendo uso del modelo de elevación digital generado por INEGI para toda la República.

A NIVEL REGIONAL-LOCAL

En la actualidad, adicionalmente a la base de datos descrita anteriormente para todo el país, se desarrollan bases de datos más específicos a nivel regional o local. Estas poseen algunos rasgos distintivos como la resolución de las imágenes en donde en la mayoría de los casos se ha pasado de una área mínima cartografiable de 900 x 900 m a una de 90 x 90 m, dando como resultado una mejor representación de la disponibilidad de los recursos del medio físico.

Otro carácter distintivo es la realización de estudios de campo para levantar la información de variables físico-químicas y de fertilidad de suelos. Esta información es cartografiada utilizando programas de interpolación compilados en TURBO C, los cuales generan imágenes que son posteriormente documentadas en el GIS IDRISI produciendo así bases de datos mucho más descriptivas a nivel local.

En el aspecto climático, se han comenzado a implementar bases de datos diarios utilizando el enlace de los sistemas CLICOM-SICA -Sistema de

Información para Caracterizaciones Agroclimáticas- (Medina y Ruiz, 1992) para generar parámetros adicionales como probabilidades de lluvia, período libre de heladas, estación de crecimiento, etc. y cartografiarlos mediante programas de interpolación, los cuales también están siendo constantemente actualizados.

Las regiones que han comenzado con este tipo de trabajos son la región Pacífico Centro con sede en Guadalajara, Jalisco y la región Centro con sede en Toluca, México (INIFAP, 1994; Vizcaíno et al, 1995; Tapia et al, 1995; Ruiz et al, 1995)

ESTRATEGIA REGIONALIZADORA

Dado que el monitoreo de agroecosistemas y la obtención de bases de datsos a nivel regional-local representan un arduo y costoso trabajo, el cual se multiplica cuando si se considera que México es un país de una amplia gama de condiciones ambientales y por ello también de una gran diversidad de agroecosistemas, el INIFAP recientemente ha considerado estratégico estratificar al país de acuerdo a sus condiciones ambientales, para tratar de eficientar los recursos de investigación destinados a estas labores. Para lograr esta estratificación se ha utilizado una clasificación generada por investigadores del propio Instituto (INIFAP, 1996) y que ha sido producto de adaptaciones hechas a sistemas previos de clasificación climática, los cuales no satisfacían por completo las necesidades de un sistema consistente para utilizarse en planificación de la investigación, generación y transferencia de tecnología.

El sistema contempla tres niveles de estratificación:

Primer nivel: Estratificación por temperatura, considerando la influencia latitudinal. De acuerdo con FAO (1981) se utilizan temperaturas corregidas a nivel del mar. Los estratos son:

a) Trópico. La temperatura del mes más frío es superior a 18 C.
b) Subtrópico. La temperatura del mes más frío es inferior a 18 C pero superior a 5 C.
c) Templado. La temperatura del mes más frío es inferior a 5 C .

Segundo nivel: Estratificación por humedad. Se refiere a la disponibilidad de humedad para soportar el desarrollo de cubiertas vegetales. Los estratos son:

a) Húmedo. Por lo menos 7 meses con precipitación (P) > 0.8 evaporación (E).
b) Subhúmedo. De 4 a 6 meses con P > 0.8 E.
c) Semiárido. De 1 a 3 meses con P > 0.8 E.
d) Arido. Ningún mes con P > 0.8 E.

Tercer nivel: Estratificación por temperatura, considerando la influencia altitudinal. Se utilizan temperaturas sin corregir a nivel del mar. Los estratos son:

a) Muy cálido. Temperatura media anual > 26 C.
b) Cálido. Temperatura media anual entre 22 y 26 C.
c) Semicálido. Temperatura media anual entre 18 y 22 C.
d) Fresco. Temperatura media anual entre 14 y 18 C.
e) Frío. Temperatura media anual < 14 C.

De acuerdo con esta estratificación, existen en México un total de 28 ambientes, a saber:

Trópico muy cálido árido
Trópico muy cálido semiárido
Trópico muy cálido subhúmedo
Trópico muy cálido húmedo
Trópico cálido árido
Trópico cálido semiárido
Trópico cálido subhúmedo
Trópico cálido húmedo
Trópico semicálido árido
Trópico semicálido semiárido
Trópico semicálido subhúmedo
Trópico semicálido húmedo
Subtrópico cálido árido
Subtrópico cálido semiárido
Subtrópico cálido subhúmedo
Subtrópico cálido húmedo
Subtrópico semicálido árido
Subtrópico semicálido semiárido
Subtrópico semicálido subhúmedo
Subtrópico semicálido húmedo
Subtrópico fresco árido
Subtrópico fresco semiárido

Subtrópico fresco subhúmedo
Subtrópico fresco húmedo
Templado fresco árido
Templado fresco semiárido
Templado fresco subhúmedo
Templado fresco húmedo

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SUBJECT VII: DEVELOPING WORKABLE INITIATIVES

Central to the discussions of this plenary panel was the need for and practicability of developing joint monitoring efforts for ecological assessment. From previous Workshop sessions, a representative from each ecosystem resource group summarized findings and recommendations, and presented and discussed recommendations and proposals for cooperative and collaborative research, development, and application initiatives.

Summary of Research and Development Needs for Monitoring Forest and Rangeland Ecosystems

Douglas S. Powell[1]

Abstract.—A summary and synthesis of the workshop session on research and development needs for the forest and rangeland resource group identified these major conclusions: emergence of a new culture of cooperation and collaboration, importance of considering proper spatial and temporal scales, need for extensive sample and intensive research site networks in monitoring system with initial focus on the former, development of simple and low cost monitoring system, importance of adaptive monitoring, assurance of high quality information, and need for governments to initiate action in conjuction with support from many other sources.

Summarizing the results of the session on research and development needs for the forest and rangeland resource group is a challenge. We covered many topics and issues in 2 1/2 hours and heard excellent presentations from six speakers representing the three countries at this workshop. While the ideas I'll share came from one resource group, in many cases they apply widely and will probably be mentioned by other speakers as well. Most of the outcomes from the session are conclusions with a few recommendations. There was insufficient time to develop initiatives.

In this session we identified the emergence of a new culture for our three countries. This workshop was only the beginning step. We now need to involve other experts and interested parties. Stakeholders are important and we must be as inclusive as possible. With declining budgets and fewer trained people available in our various governments, we must communicate, coordinate, and collaborate even more than we have to date. We need to work hard to avoid duplication that wastes precious time and money. One possible example in the U.S. is to find a way to somehow merge or combine the Forest Inventory and Analysis (FIA) and Forest Health Monitoring (FHM) programs.

Identifying the proper scale or scales (both spatial and temporal) related to many issues for forests and rangelands. We must know the scale that we are monitoring at because questions, objectives, and perspectives vary by scale. For example, as scales shift from global to local the issues become more numerous, detailed, complex, and difficult.

Throughout this workshop we have heard reference to extensive samples versus intensive research sites for monitoring. Both are necessary for an effective framework, and ideally progress to develop networks of both kinds should proceed simultaneously. However, if resources are so limited as to force a choice, our resource group's consensus was to focus attention first on the extensive samples and then pick up the intensive sites later. Our reasons for emphasizing the extensive sampling network are: (1) early warning detection of problems, (2) assures representation, i.e., "all bases are covered," (3) generates hypotheses for testing at intensive sites, (4) useful to help in proper placement of intensive sites, (5) necessary to answer the "what is the problem?" question before the "why is it happening?" question, and (6) there are big gaps in current extensive network that are hinder-

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ing progress, e.g., weather stations and grassland sites in Mexico. For forest ecosystems, there is an excellent opportunity to bring together the extensive samples of the Acid Rain Early Warning System (ARNEWS) and Canadian Forest Inventory; the FIA, FHM, and Natural Resources Inventory (NRI) in the U.S.; and the forest inventory network in Mexico to create a North American framework.

Development of a low cost, simple monitoring system should be our goal. Look hard at existing data before collecting more—for forest ecosystems we have a rich, fertile field for analysis of existing information. Try to identify a small set of core variables (one speaker suggested using six as a starting point for forest monitoring: tree species, diameter, height, growth, age, and status or history) and then others could be added at the option of a country or region. Research can help here by focusing on low cost monitoring technology and equipment, e.g., automatic remote monitoring stations and Advanced Very High Resolution Radiometer (AVHRR) satellite data.

Taking the lead from adaptive management, which is receiving widespread attention, our monitoring should be adaptive as well. There will be a need for continuous improvement. An important task may be to "monitor the monitoring." This process of self-examination and improvement is required in order for our monitoring system to maintain its relevancy and sufficiency.

Whatever data or information result from monitoring, they must be of high quality. We need to plan to assure that data are of sufficient quality to meet the stated objective of the monitoring. Minimum quality assurance standards must be set for all three countries.

The final major topic from our session was a practical one—who should do the monitoring? A consensus was that federal and state/province governments would take the lead while working in close cooperation with universities, industry, non-government organizations, and commissions. The monitoring system must be customer driven and science based (not the other way around). All customers, stakeholders, and interested parties must be involved from the start (setting objectives) through the end (receiving results in easy, timely, and understandable reports and through other media). Multi-disciplinary teamwork is a necessity, involving such experts as biologists, ecologists, geographers, social scientists, and computer scientists.

In conclusion, the borders between Canada, the U.S., and Mexico are political but not useful for monitoring the forest and rangeland ecosystems of North America. Let's dissolve these borders and work together.

Following the presentation, these two comments were received:

(1) The International Union of Forestry Research Organizations (IUFRO) has already developed a core set of data. I recommend these be adopted as the minimum. A 1994 publication, "IUFRO International Guidelines for Forest Monitoring," is available from IUFRO headquarters in English and Spanish. [Gyde Lund, U.S. Forest Service]

(2) When we are discussing whether to develop intensive monitoring systems or extensive monitoring systems to meet the needs of our customers, we need to define what those needs are. This has been done on the national and international levels for forests by the criteria and indicators elucidated in the 1995 Santiago Declaration. I suggest that this workshop adopt the principles of the Santiago Declaration as the goal of any monitoring programs developed among our countries, to give focus to our monitoring programs. [Kenneth W. Stolte, U.S. Forest Service]

GENERAL SUMMARY, WORKSHOP SYNTHESIS, AND RECOMMENDATIONS

General Summary

J.J. Molina[1]

This panel discussion focused on the need and practicability of developing joint monitoring efforts for ecological assessment among the three countries. Rapporteours and participants from panel discussions on subjects V and VI presented an overview of the issues that were raised by their respective groups and gave a summary of recommendations regarding priority needs for research and ideas on specific initiatives that would contribute to developing a general framework for collaboration.

PLENARY SPEAKER

The session was initiated with a presentation by Dr. Michael Ruggiero (National Biological Service, U.S. Department of Interior), who spoke on "Bridging Gaps of Monitoring for Ecological Assessment Across Ecosystems Resource Groups". He shared his experience in leading the development of a national framework for integrating and coordinating environmental monitoring and related research through collaboration and building on existing networks.

There are over 30 major networks operating in the north american continent. In the process of integrating these major networks to answer specific needs of monitoring and assessment, specific and general protocols have been developed. These could be useful to other groups developing their own networks, or to link existing networks; there is interest in linking to networks in Canada, for example.

At the moment the trend appears to be in the direction of increasing funding for academic research.

RAPPORTEOURS' SUMMARIES OF SESSION V

1. Indicators (Dr. Martín López, Rapporteour).

A summary of the different presentations in this team session was presentd by Dr. López. The need for the proper selection of indicators according to the objectives of monitoring efforts was emphasized. Many techniques are being applied to monitoring for the assessment of ecosystems, from simple measurements of anatomical dimensions in wild animals, to satelite imagery; it was stressed that a proper selection of indicators should consider the need for prediction as an important component of the monitoring effort.

2. Quality Assurance and Information Management (Dr. Craig Palmer, Rapporteour).

Dr. Palmer presented an overall recommendation from the U.S. and Canadian scientists to their Mexican colleges: to share in their experience on quality assurance and quality control of the information by participating in the upcoming workshop on QA/QC to be held in 1996. Candidates willing to participate in this workshop were urged to contact Dr. John Lawrence or Dr. Palmer. Dr. Martín López and Dr. José Molina signed up.

3. Analysis, Assessment and Reporting (Dr. José Luis Romo, Rapporteour).

Different analysis techniques and methods for reporting information generated by monitoring studies were discussed in this team session, and were presented in an overview/summary by Dr. Romo.

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It was proposed that all analysis techniques should allow for a proper estimation of ecosystem health. Research should be aimed at supporting ecosystem conservation policies.

It was agreed that it is important to define the basic questions to be answered so that the proper indicators are selected and the proper analysis techniques are applied.

On reporting, the need to inform the public was considered as critical as the need to communicate among scientists.

4. Design and Statistics (there was no rapporteour for this team session, so the information was not presented).

RESEARCH AND DEVELOPMENT NEEDS (SUMMARIES FROM SESSIONS ON SUBJECT VI)

1. Forest and Range Lands (Dr. Douglas Powell, USDA Forest Service).

During this discussion session, no initiatives were advanced, however the following major issues were examined and reflected upon:

a. The need to establish a new culture in research: the need to involve other experts and the general public to express their views was recognized. Communication and collaboration should prevent the duplication of efforts.
b. The need to define scale: the importance of defining the scale at which monitoring is done, was the general agreement. Issues tend to be more detailed, complex and difficult to handle as we come down to a location scale (as opposed to a global one).
c. Extensive sample sites as opposed to intensive research sites: the overall view was that extensive sample sites should be used as early warning systems for the detection of specific problems; these results should generate a hypothesis to be tested at intensive research sites. It was recognized that Mexico has many gaps in their network for extensive sampling locations.
d. Monitoring systems should be simple and inexpensive: the need for research on low-cost monitoring equipment was discussed.
e. Adaptive monitoring: there is need for more flexibility ad improvement in monitoring systems so that they could be adapted to different situations.
f. Quality of information: it was considered that in general, the quality of the information that is being generated is sufficient to meet the objectives; however, the need to implement minimum quality assurance standards for the three countries was recognized.
g. Who should be involved?: the federal governments working closely with univiersities and NGO's should be involved in research efforts. The system should be customer-driven but scientifically-based. Interdisciplinary team-work should be encouraged (geographers, compurter scientists, information managers, etc.).

Dr. Powell ended his presentation stating that "... borders are political but are not useful for monitoring; let's dissolve these borders and work together".

2. Surface Waters, Wetlands, Estuaries and Coastal Waters (Dr. Peter Vaux, University of Nevada, Las Vegas).

Dr. Vaux initiated his presentation by showing the relative importance given by the discussion group to three important aspects related to monitoring: communication was the most important issue, with 41 % of the weight, economical aspects ranked second with 33 %, and effective indicators in third place with 26 % of the weight.

a. Communication: there is a general need for more effective coummunication not only among scientists, but between scientists and the communities that are being affected by the monitoring process, as well as with people and groups responsible for legislation and policy making.
b. Economical aspects: there is a need to bring "ecological economics" into the process of monitoring. The economic use of surface waters (fishing, generation of electricity, etc.) should be considered in the

management of an ecological monitoring program, and should reinforce the selling of the idea of monitoring.

c. Effective indicators: several issues were considered including biomarkers and ecology, the analysis of cause-effects in the selection of indicators, the need for intercalibration of biological responses, the need for economical sampling techniques, and a rigorous evaluation of the usefulness of indicators that are being used based on tradition.

3. Agroecosystems (Dr. Terance McRae, Agriculture and Agrifood Canada).

The importance of agriculture in the three countries was recognized, not only as an important source of employment for the rural communities, but as an essential component of GNP. Lands dedicated to agriculture should be managed in a sustainable way so that they may continue to provide employment and economic wealth.

Dr. McRae gave a quick review of the different presentations included in this resource group session, and summarized the main issues that were identified:

a. Policy relevance: the recommendation was that all monitoring should be focused on issues of importance.
b. Expertise: should be developed and enhanced; special attention should be given to understanding linkages and how to properly use models.
c. Data: once again, the issues of quality, consistency, and integration of data were raised.
d. Communication and interpretation: there is a need to communicate results in a way that makes sense to the public.
e. Extensive vs intensive monitoring: this group favors the idea of doing intensive monitoring first, to set the priorities for extensive monitoring efforts.

Finally Dr. McRae posed the question: "Where do we go from here?". A fundamental issue is to understand the data that exists and understand it better. There are important similarities among the three countries and a willingness to collaborate. There are agreements at the international level that should allow for the establishment of indicators common to all three countries for the monitoring of agroecosystems.

At the end of this presentation, the session was opened for disussion and comments.

A proposal was advanced to establish pilot intensive monitoring sites in Mexico. However, no mechanism as to how to achieve this was described.

It was suggested that a team of scientists from the three countries should be integrated to identify common objectives and examine existing data, so that a strategy of monitoring could be proposed. White papers have already been drafted to that effect.

A comment was made to the effect that no discussion on artic ecosystems or desert ecosystems were considered in this workshop. These are very important to Canada and Mexico, and should have been addressed. It was proposed that a mechanism should be designed to allow scientists to get together in separate workshops to address these specific issues. These should cover more tactical subjects, eg. smaller programs that are not as complex as EMAP.

In closing remarks, Dr. Andrew Hamilton, panel moderator for this plenary session, emphasized the need to consider the local wisdom of natives in ecosystems, who have learned over the centuries how to manage properly their surrounding environment.

Dr. Celedonio Aguirre, general coordinator of this workshop, concluded that this event is only the beginning of an "adventure" in trinational work on ecological monitoring.

Ing. Sergio Reyes Osorio, with the personal representation of Dr. Oscar González Rodríguez, Undersecretary of Natural Resources of SEMARNAP, Mexico, made the formal closing of this workshop, recognizing the relevance and importance of this event for the present and future of our natural resources. He voiced his wish that this event will initiate a road to cooperation among the three nations.

WORKSHOP SYNTHESIS

The participants of the workshop on monitoring for ecological assessment of terrestrial and aquatic ecosystems concurred that monitoring and assessment are scientifically based approaches to:

- Understanding and reporting on the status and trends in ecosystem condition;
- Describing emerging ecological problems;
- Aiding in the design of environmental management activities;
- Evaluating environmental management programs in terms of their performance;
- Responding to ecological emergencies.

In essence, ecological monitoring strives to determine what is changing in the environment and why, in support of informed and responsible decision making.

The participants agreed that social and economic considerations are important factors in the design, execution, and reporting of any monitoring and assessment program.

Ecological monitoring must be supported by appropriate quality management approaches and methodologies.

SPECIFIC RECOMMENDATIONS

- The preparation of a tri-national document laying out a framework for action;
- The framework should include activities and mechanisms to foster and encourage tri-national cooperation and collaboration and to further develop ecological monitoring in North America;
- The participants agreed that it is essential to establish on-going mechanisms to facilitate this process.

The North American agreement on environmental cooperation between the governments of Canada, the united Mexican states and the united states of America contains many references to the need to facilitate and increase environmental cooperation. It also provides for a commission for environmental cooperation to assist the governments in implementing the agreement. The governments may wish to use the commission for environmental cooperation as one means of providing the facilitation mechanisms referred to above.

SINTESIS DEL TALLER

Los participantes en este taller sobre monitoreo para la evaluación de los ecosistemas terrestres y acuaticos acordaron que el monitoreo y la evaluación son procedimientos cientificamente fundamentados que permiten:

- Entender y divulgar el estado actual y las tendencias de la condición de los ecosistemas;
- Describir los problemas ecológicos emergentes;
- Auxiliar en el diseno de actividades relacionadas con el manejo del medio ambiente;
- Evaluar los programas de manejo del medio ambiente en terminos de sus resultados;
- Responder a las emergencias ecológicas.

En esencia, el monitoreo y la evaluación ecológica nos permiten determinar que cambios estan ocurriendo en el medio ambiente y porque; lo anterior con el proposito de apoyar con información confiable y de manera responsable los procesos de toma de decisiones.

Los participantes acordaron que los aspectos sociales y económicos son factores fundamentales en el diseno, ejecución y difusión de cualquier programa relativo al monitoreo ecológico y de evaluación.

El monitoreo ecologico debe estar apoyado por estrategias y metodologias apropiadas para el manejo del control de calidad de la información.

RECOMENDACIONES ESPECIFICAS

- Elaborar un documento trinacional que contenga el plan de acciones concretas sobre monitoreo ecológico y evaluación para llevarlas a cabo;
- El plan de acciones debera incluir actividades y mecanismos que permitan reforzar y promover la cooperacion y la colaboracion trinacional que coadyuven a un mejor desarrollo del monitoreo ecologico en Norteamerica;
- Los participantes acordaron que es esencial establecer mecanismos activos y eficientes para facilitar este proceso.

El acuerdo de cooperacion ambiental para Norteamerica entre los gobiernos de Canada, Estados Unidos y México incluye diversas referencias sobre la necesidad de facilitar e incrementar la cooperacion sobre el medio ambiente. En el tambien se establece crear una comision para la cooperación ambiental que apoye a los gobiernos de los tres paices en implementar dicho acuerdo. Los gobiernos pueden hacer uso, si asi lo consideran, de la comisión para la cooperacion ambiental como el medio adecuado que se encargue de facilitar los mecanismos anteriormente mencionados.

Acta de la Reunión Trinacional de Ejecutivos que Asistieron al Taller Norteamericano Sobre Monitoreo para la Evaluación Ecológica de Ecosistemas Terrestres y Acuáticos

Lugar y Fecha: Ciudad de México, Septiembre 21, 1995.

ASISTENTES

México: Ing. Sergio Reyes Osorio (General Director of Forestry) representing the Undersecretary of Natural Resources (Dr. Oscar Gonzalez Rodriguez), Secretariat of Environment, Natural Resources and Fisheries (SEMARNAP); Ing. Sergio Varela Hernandez (Director, National Inventory of Natural Resources, SEMARNAP); Ing. Carlos Gonzalez Vicente (Deputy Chief for Forestry Research, INIFAP, SAGAR); Dr. Jose Molina Ruiz (Director, Scientific Research and Postgraduate Studies, Universidad Autonoma de Chihuahua).

Estados Unidos de America: Dr. Sidney Draggan (Asesor Científico, U.S. Environmental Protection Agency); Dr. Denver P. Burns (Director, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service); Dr. Michael Ruggiero (Coordinador Nacional de Monitoreo Ecológico, U.S. Department of the Interior); Dr. Douglas Powell (Coordinador Nacional de Monitoreo Ecológico, USDA Forest Service); Dr. Celedonio Aguirre Bravo (Coordinador de la Cooperacion Forestal Cientifica con Mexico, RM-USDA Forest Service).

Canada: Dr. Thomas Brydges (Director, Ecological Monitoring, Canada Environment); Dr. Andrew Hamilton (Jefe de la División Científica de la Comisión Para la Cooperación Ambiental).

OBJETIVOS DE LAREUNION

Presentar a las Autoridades de SEMARNAP las Principales Conclusiones y recomendaciones que surgieron del taller asi como de analizar los mecanismos para darle seguimiento a las recomendaciones planteadas.

ASUNTOS QUE SE TRATARON

- Presentacion de la sintesis del taller;
- Presentacion de las recomendaciones especificas que resultaron del taller;
- Mecanica para el seguimiento de las recomendaciones planteadas.
- Comentarion por parte de los ejecutivo de los paices participantes.

Se anexa la informacion sobre la sintesis del taller y de las recomendaciones especificas que se presentaron y analizaron en esta reunion.

Por parte de Canada, Estados Unidos y México firman esta acta de la reunion los siguientes ejecutivos:

ING. SERGIO REYES OSORIO

ING. SERGIO VARELA H.

DR. THOMAS BRYDGES

DR. ANDREW HAMILTON

DR. DENVER P. BURNS

DR. SIDNEY DRAGGAN

Minutes of the Trinational Meeting of Executives Who Attended the North American Workshop on Monitoring for Ecological Assessment of Terrestrial and Aquatic Ecosystems

Place and Date: Mexico City, September 21, 1995.

ATTENDING:

Mexico: Ing. Sergio Reyes Osorio (General Director of Forestry) representing the Undersecretary of Natural Resources (Dr. Oscar Gonzalez Rodriguez), Secretariat of Environment, Natural Resources and Fisheries (Semarnap); Ing. Sergio Varela Hernandez (Director, National Inventory of Natural Resources, SEMARNAP); Ing. Carlos Gonzalez Vicente (Deputy Chief for Forestry Research, INIFAP, SAGAR); Dr. Jose Molina Ruiz (Director, Scientific Research and Postgraduate Studies, Universidad Autonoma De Chihuahua).

United States of America: Dr. Sidney Draggan (Special Assistant for Science, Administrator's Office, U.S. Environmental Protection Agency); Dr. Denver P. Burns (Director, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service); Dr. Michael Regear (Chief, Surveys and Inventory Division, U.S. Department of the Interior); Dr. Douglas Powell (National Monitoring Coordinator, USDA Forest Service); Dr. Celedonio Aguirre Bravo (Research Coordinator With Mexico, USDA Forest Service).

Canada: Dr. Thomas Brydges (Director, Ecological Monitoring, Canada Environment); Dr. Andrew Hamilton (Chief, Science Division, Commission For Environmental Cooperation).

OBJECTIVES OF THE MEETING

To present to SEMARNAP'S authorities the principal conclusions and recommendations that resulted from the workshop and to analyze the mechanisms for follow up on the proposed recommendations.

AGENDA ITEMS

- Presentation of workshop synthesis;
- Presentation of the specific recommendations that resulted from the workshop;
- Mechanisms for follow up on the proposed recommendations;
- Comments from executives of the participating countries.

Enclosed is the information on the workshop synthesis and the specific recommendations that were presented and discussed in this meeting.

The minutes of this meeting are signed by the following executives from Canada, United States of America and Mexico:

ING. SERGIO REYES OSORIO

ING. SERGIO VARELA H.

DR. THOMAS BRYDGES

DR. ANDREW HAMILTON

DR. DENVER P. BURNS

DR. SIDNEY DRAGGAN

Workshop Organizational Structure

EXECUTIVE COMMITTEE

MEXICO

Vocal Forestal, Ing. Carlos Gonzalez Vicente, Secretaria de Agricultura, Ganaderia y Desarrollo Rural (SAGAR), Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP).

Director, Alejandro E. Castellanos, Centro de Investigaciones Cientificas y Tecnológicas de la Universidad de Sonora (CICTUS).

Director, Dr. Jose J. Molina Ruiz, Universidad Autónoma de Chihuahua (UACH), Direccion de Investigación y Postgrado (DIP).

Director, Dr. Eduardo Narro Farias, Universidad Autónoma Agraria Antonio Narro (UAAAN), Subdireccion de Investigacion Cientifica (SIC).

Director, Ing. Sergio Reyes Osorio, SEMARNAP, Dirección General de Aprovechamientos Forestales (DGAF).

Director, Dr. Hugo Ramirez Maldonado, Universidad Autónoma Chapingo (UACH), Dirección General de Postgrado CDGP).

U.S.A

Director, Dr. Denver P. Burns, United State Department of Agriculture (USDA), Forest Service (FS), Rocky Mountain Forest and Range Experiment Station (RM).

USEPA-EMAP, Special Assistant for Science, Administrator's Office, U.S. Environmental Protection Agency, Dr. Sidney Draggan.

CANADA

Director, Dr. Thomas Brydges, Ecological Monitoring Coordinating Office (EMCO), Environment Canada (EC).

Dr. Andrew L. Hamilton, Head of the Science Division (HSD), Commission for Environmental Cooperation (CEC).

GENERAL COORDINATION COMMITTEE

MEXICO

Ing. Carlos Gonzalez Vicente, Vocal Forestal, SAGDR-INIFAP.

Ing. Sergio Varela, Director, Inventario National de Recursos Naturals, SEMARNAP.

Mr. John Ryan ,SEMARNAP, Coordinación de Asuntos Internacionales.

U.S.A.

Dr. Craig J. Palmer (USEPA-EMAP).

Dr. Thomas W. Hoekstra (USDA Forest Service).

Dr. Celedonio Aguirre-Bravo (USDA Forest Service).

CANADA

Dr. Thomas Brydges, Ecological Monitoring Coordinating Office, Environment Canada.

Dr. Andrew L. Hamilton, Head of the Science Division, Commission for Environmental Cooperation.

STEERING COMMITTEE MEMBERS (CANADA, U.S., AND MEXICO)

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U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of seven regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota

*Station Headquarters: 240 W. Prospect Rd., Fort Collins, CO 80526